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UMTRA Ground Water Project

Work Plan for Characterization Activities at the UMTRA Project New and Old Rifle Sites

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Note: Some of the section page numbers in the Table of Contents may not correspond to the page on which the section appears when viewing them in Adobe Acrobat.

Contents

1.0 Introduction 1–1
1.1 Purpose and Scope 1–1
1.2 Site Background 1–1
1.2.1 Old Rifle Millsite 1–1
1.2.2 New Rifle Millsite 1–5
1.2.3 Target Compliance Strategy 1–6

2.0 Geologic Setting 2–1
2.1 Regional Geology 2–1
2.2 Local Geology 2–1
2.2.1 Geology at the Old Rifle Site 2–2
2.2.2 Geology at the New Rifle Site 2–2
2.3 Summary of Data Needs 2–14

3.0 Hydrogeology 3–1
3.1 Surface-Water Hydrology 3–1
3.1.1 Old Rifle Site 3–1
3.1.2 New Rifle Site 3–2
3.2 Alluvial Aquifer 3–3
3.2.1 Old Rifle Site 3–3
3.2.2 New Rifle Site 3–4
3.3 Wasatch Formation 3–8
3.3.1 Old Rifle Site 3–8
3.3.2 New Rifle Site 3–13
3.4 Summary of Hydrologic Data Needs 3–14
3.4.1 Surface Water 3–14
3.4.2 Ground Water 3–14

4.0 Geochemistry 4–1
4.1 Source Areas and Contaminants 4–1
4.1.1 Quantity Estimates of Process Water and Chemicals 4–2
4.2 Source Area Contamination 4–2
4.3 Alluvial Aquifer Contamination 4–3
4.3.1 Extent of Alluvial Ground-Water Contamination 4–5
4.4 Plume Migration 4–16
4.5 Bedrock Aquifer Contamination 4–22
4.6 Surface-Water Contamination 4–29
4.7 Summary of Geochemical Data Needs 4–33
4.7.1 Source Area Characterization 4–33
4.7.2 Monitor Well Network 4–33

5.0 Ecology 5–1
5.1 Summary of the Screening-Level Risk Assessment 5–1

Contents (continued)

5.1.1 Ecological Contaminants of Potential Concern 5–1
5.1.2 Potential Receptors 5–3
5.1.3 Potential Adverse Effects 5–5
5.2 Summary of Ecological Data Needs 5–6

6.0 Site Conceptual Model 6–1
6.1 Surface-Water Features 6–1
6.1.1 Old Rifle Site 6–1
6.1.2 New Rifle Site 6–1
6.2 Ground Water 6–2
6.2.1 Old Rifle Site 6–2
6.2.2 New Rifle Site 6–2
6.3 Ground-Water Quality 6–3

7.0 Data Quality Objectives 7–1
7.1 Data Quality Objectives at the Old Rifle Site 7–1
7.2 Data Quality Objectives at the New Rifle Site 7–5
7.3 Rationale for Data Quality Objectives and Data Collection Strategies 7–12
7.3.1 Alluvial Lithology and Water Quality of the Alluvial Aquifer 7–12
7.3.2 Contaminant Sorption in the Alluvial Aquifer 7–14
7.3.3 Hydrologic Properties of the Alluvial Aquifer 7–14
7.3.4 Characterization of Subpile Soil 7–15
7.3.5 Plant Ecology and Land Use 7–16
7.3.6 Surface Water and Sediment Contamination 7–16
7.3.7 Lithology and Water Quality of the Upper Wasatch Formation 7–17

8.0 Site Investigation Procedures 8–1
8.1 Ground-Water Monitoring Well, Temporary Well, and Hydropunch Installations . 8–1
8.2 Soil and Rock Sample Collection for Lithologic Logging, Kd, and
Subpile Soil Analysis 8–2
8.3 Ground-Water Sampling 8–7
8.4 GJO Analytical Laboratory Sample Analyses 8–8
8.5 Hydrologic Tests 8–8
8.5.1 Measurements of Water Levels Using a Data Logger 8–9
8.5.2 Step-Drawdown Aquifer Test 8–9
8.5.3 Aquifer Tests 8–10
8.6 Land Surveys 8–11
8.7 Vegetation Sampling and Analysis 8–11
8.8 Quality Assurance and Quality Control 8–11
8.8.1 Sampling Procedures 8–12
8.8.2 Sample Control 8–12
8.8.3 Laboratory Quality Control 8–12
8.8.4 Field Quality Control 8–13

Contents (continued)

9.0 Environmental Compliance Requirements/Actions 9–1
9.1 Environmental Assessment 9–1
9.2 Well Installation/Water Use 9–1
9.3 Cultural Resources Issues 9–1
9.4 Wetlands/Floodplain 9–1
9.5 Threatened and Endangered Species 9–2
9.6 Off-Road Activities 9–2
9.7 Transportation of Samples and Reagents 9–2
9.8 Waste Management 9–2
9.8.1 Regulatory Requirements 9–2
9.8.2 On-Site Disposal of IDW 9–4
9.8.3 Off-Site Disposal of IDW 9–5
9.8.4 Management of Spills 9–7
9.8.5 Waste Transportation and Disposal 9–8

10.0 Health and Safety 10–1

11.0 Logistics and Schedule 11–1
11.1 Work Readiness Review 11–1
11.2 Schedule 11–2

12.0 Deliverables 12–1

13.0 References 13–1

Figures

Figure1–1. Location of the New and Old Rifle Sites 1–2
1–2. Details of the Old Rifle Site 1–3
1–3. Details of the New Rifle Site 1–7
2–1. Regional Geologic Map of the Rifle Area 2–3
2–2. Generalized Regional Geologic Cross-Section, Rifle Sites 2–5
2–3. Local Geology at the Old Rifle Site 2–7
2–4. Generalized Geologic Cross Section , Old Rifle Site 2–9
2–5. Local Geology at the New Rifle Site 2–11
2–6. Generalized Geologic Cross-Section, New Rifle Site 2–13
3–1. Generalized Water Table Contour Map for the Alluvial Aquifer,
Old Rifle UMTRA Ground Water Site 3–5
3–2. Generalized Water Table Contour Map for the Alluvial Aquifer,
New Rifle UMTRA Ground Water Site 3–9

Figures (continued)

3–3.Generalized Potentiometric Surface Map for the Wasatch Formation, Old Rifle UMTRA Ground Water Site 3–11
3–4. Generalized Potentiometric Surface Map for the Wasatch Formation, New Rifle UMTRA Ground Water Site 3–15
4–1. Extent of Ammonium Contamination in the Alluvial Aquifer at the New Rifle Site 4–7
4–2. Extent of Nitrate Contamination in the Alluvial Aquifer at the New Rifle Site 4–11
4–3. Extent of Selenium Contamination in the Alluvial Aquifer at the New Rifle Site 4–13
4–4. Extent of Uranium Contamination in the Alluvial Aquifer at the New Rifle Site 4–17
4–5. Extent of Vanadium Contamination in Alluvial Aquifer at the New Rifle Site 4–19
4–6. Uranium Concentration Versus Time for Selected On-Site Monitor Wells at the New Rifle Site 4–21
4–7. Areal Distribution of Increasing and Decreasing Uranium Concentrations at the New Rifle Site 4–23
4–8. Uranium Concentrations Versus Time for Selected Off-Site Monitor Wells at the New Rifle Site 4–21
4–9. Uranium Concentrations in the Wasatch Aquifer at the New Rifle Site 4–25
4–10. Uranium Concentrations in the Wasatch Aquifer at the Old Rifle Site 4–27
4–11. Uranium Concentrations in Surface Water at the New and Old Rifle Sites 4–31
4–12. Uranium Concentrations in the Roaring Fork Gravel Pond Located Downgradient from the New Rifle Site 4–30
7–1. Proposed Location for New Monitoring Wells, Old Rifle Site 7–3
7–2. Proposed Alluvial Monitoring Well, Pumping Well, and Hydropunch Locations, New Rifle Site 7–7
7–3. Proposed Wasatch Well Locations, New Rifle Site 7–9
7–4. Diagram of Wasatch Well Completions 7–11
8–1. Typical Monitoring Well Construction for the Alluvial Aquifer 8–3

Tables

Table 4–1. Average Concentration of Selected Contaminants in Leachate from Tailings and Background Soils 4–2
4–2. Maximum Concentrations of Contaminants of Potential Concern Detected in the Alluvial Aquifer in 1996 and 1997 4–4
4–3. Uranium Concentrations in Five Nested Wasatch Monitor Wells 4–22
4–4. Uranium Concentrations in Surface Waters 4–29
5–1. Summary of Ecological Contaminants of Potential Concern in Ground Water, Surface Water, and Sediments. 5–2

Tables (continued)

5–2. Mammals, Amphibians, and Reptiles Expected to Inhabit the Mitigation Wetlands at the New Rifle Site. 5–4
5–3. Breeding Birds That May Nest in the Mitigation Wetlands at the New Rifle Site 5–4
7S1. Data Quality Objectives and Data Collection Strategies at the Old Rifle Site . . . 7–1
7S2. Data Quality Objectives and Data Collection Strategies at the New Rifle Site . . . 7–5
8–1. GJO Analytical Laboratory Sample Requirements 8–8
9–1. Summary of IDW Types, Volumes, and Disposal Methods 9–6
11S1. Schedule of Fieldwork at the New and Old Rifle Sites 11–2

Abbreviations

AEC	Atomic Energy Commission
AOC	area of contamination
BLRA	Baseline Risk Assessment
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPCs	contaminants of potential concern
CRS	Colorado Revised Statutes
CX	categorical exclusion
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQO	data quality objective
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ft	feet (foot)
GJO	Grand Junction Office
HI	hazard index
IDW	investigation-derived waste
Kd	distribution coefficient
kg	kilogram
MCL	maximum concentration limit
µg/L	micrograms per liter
µm	micrometer
mg/L	milligrams per liter
mi	miles
mL	milliliter
NEPA	National Environmental Policy Act
pCi/L	picocuries per liter
PEIS	Programmatic Environmental Impact Statement
PPE	personal protective equipment
QC	quality control
RCRA	Resource Conservation and Recovery Act
RRM	residual radioactive material
SOWP	Site Observational Work Plan
T&E	threatened and endangered
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action (Project)
USGS	U.S. Geological Survey
WRR	work readiness review

1.0 Introduction

1.1 Purpose and Scope

The New and Old Rifle Uranium Mill Tailings Remedial Action (UMTRA) Project sites are former ore-processing facilities located near the city of Rifle in Garfield County, Colorado (Figure 1–1). The New Rifle site is approximately 2 miles (mi) southwest of the city, between U.S. Highway 6 and Interstate 70. The Old Rifle site is approximately 0.3 mi east of the city. The Colorado River bounds both sites to the south. The U.S. Department of Energy (DOE) completed surface remediation of abandoned uranium mill tailings and structures associated with the former milling operations at the sites by relocating the contaminated materials to the Estes Gulch disposal cell approximately 9 mi north of Rifle. Both former processing sites are currently covered and regraded with clean fill material and reseeded.

An evaluation of inorganic contaminants in the ground water beneath the former tailings sites, conducted subsequent to completion of the surface remediation, suggests that a passive remediation approach is the most likely compliance strategy for the ground water. Two remedial action strategies that are considered viable are presented in the *Site Observational Work Plan for the UMTRA Project Sites at Rifle, Colorado* (SOWP) (DOE 1996e): (1) no remediation with application of supplemental standards, or (2) natural flushing remediation. The specific remediation strategy has not yet been determined.

This work plan formulates additional characterization data needs that are required to complete the selection of the final remediation strategy. A discussion of the additional data needs is presented in Sections 2.0 through 5.0; the site conceptual models for the Rifle sites are summarized in Section 6.0; data quality objectives are defined in Section 7.0; specific procedures that will be used to satisfy the data requirements are presented in Section 8.0. Results of the site characterization and a recommended final ground-water remediation strategy will be presented in the final SOWP upon completion of the field work.

1.2 Site Background

1.2.1 Old Rifle Millsite

The United States Vanadium Company constructed the original Old Rifle processing plant (Figure 1–2) in 1924 for the production of vanadium (Merritt 1971). In 1926 the assets of the United States Vanadium company were purchased by Union Carbide and Carbon Corporation (Union Carbide), and the United States Vanadium Corporation was established as a subsidiary (Chenoweth 1982). Vanadium was recovered from roscoelite-type ores by salt roasting, water leaching, and the addition of sulfuric acid to the water solutions to precipitate a sodium hexavanadate “red cake.” The plant closed in 1932 as a result of a shortage of ore. In 1942 Union Carbide reactivated the plant for vanadium production, and in 1946 the plant was modified to include the recovery of uranium by a sulfuric and hydrochloric acid leaching process. Operations continued until 1958.

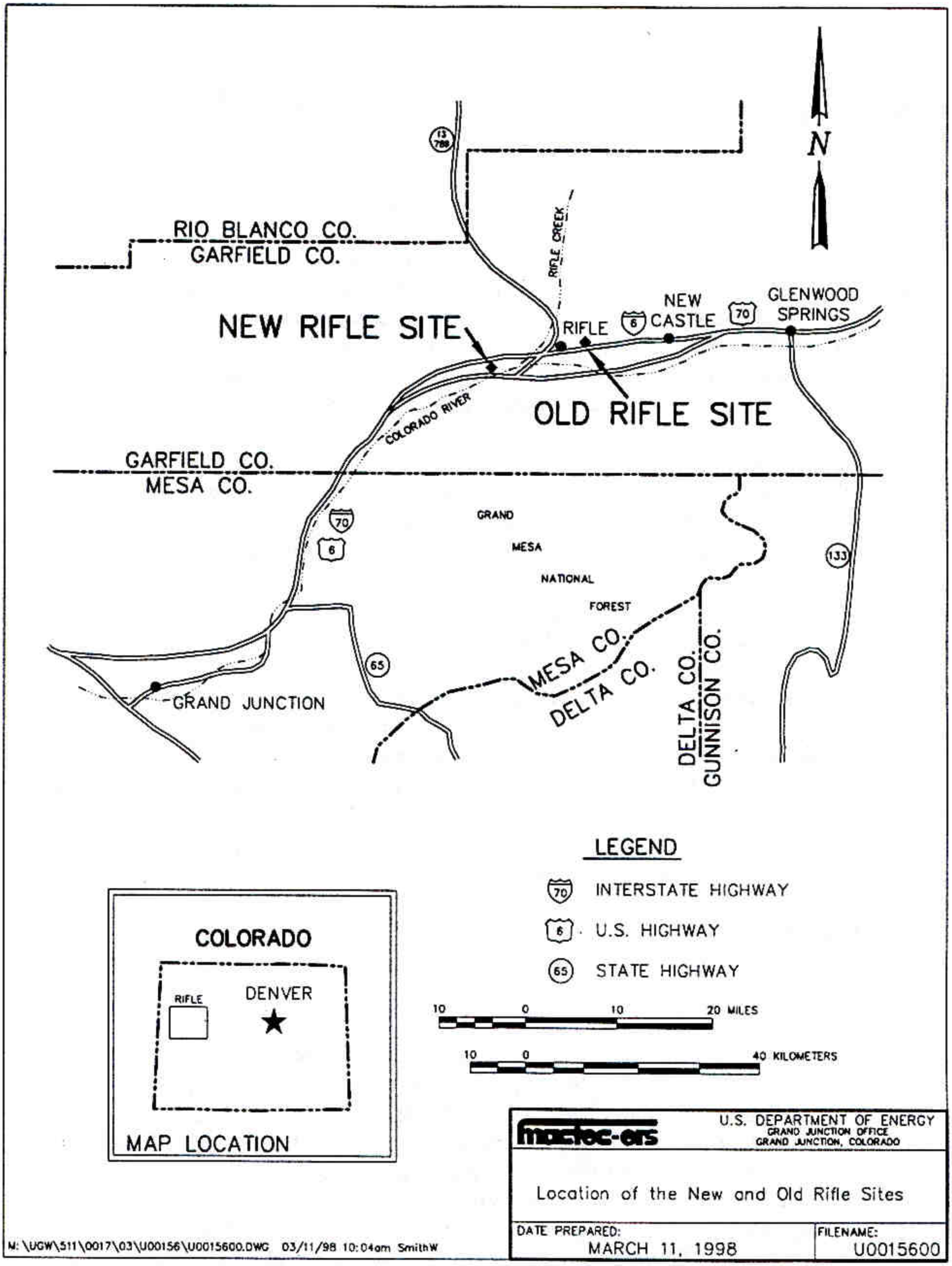


Figure 1–1. Location of the New and Old Rifle Sites

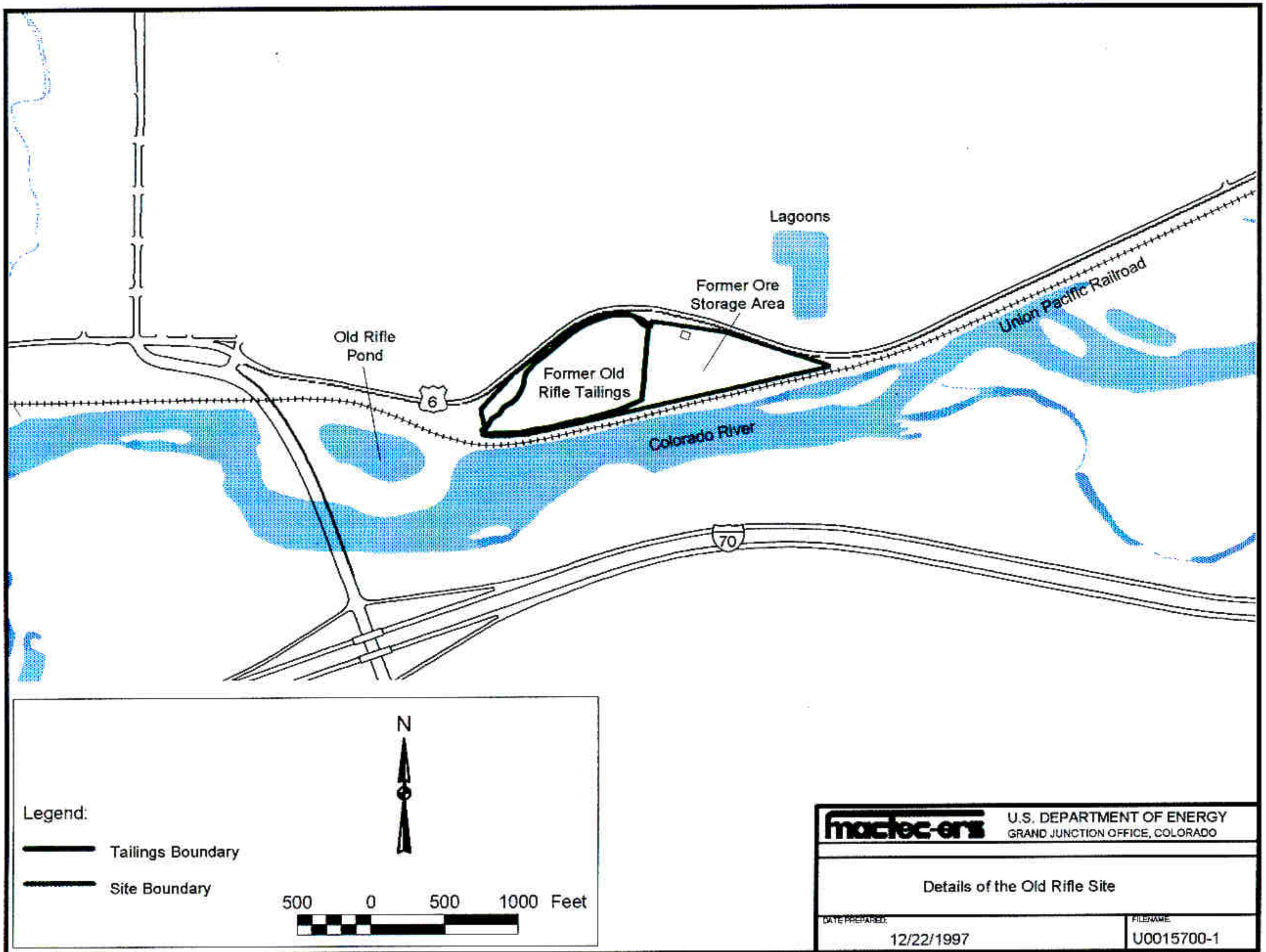


Figure 1–2. Details of the Old Rifle Site

Millfeed consisted of raw ore mined from deposits located primarily in Garfield (Garfield and Rifle Mines), Mesa, Montrose, Moffat (Meeker Mine), and San Miguel Counties in Colorado (DOE 1982). Atomic Energy Commission (AEC) records from 1947 to 1958 indicate that 693,495 tons of ore were processed at the site. Over 2,000 tons of uranium concentrate (U_3O_8) were sold to the AEC (DOE 1982).

Approximately 13 acres of tailings remained at the Old Rifle site before the surface remedial action. No structures remained at the millsite. The relatively flat tailings pile was stabilized by Union Carbide in 1967 in accordance with the State of Colorado regulations. The edge of the pile was moved away from the railroad tracks and the entire pile was covered with 6 inches of soil, fertilized, and seeded with native grasses. Water from the Colorado River was used for irrigation. Surface water draining from an upgradient seep across Highway 6 flowed through the site. The seep water collected in a lined pond after it passed the tailings pile. Overflow from the pond was released into the Colorado River. The pond and tailings were removed during surface remedial action completed in 1996.

1.2.2 New Rifle Millsite

Union Carbide constructed a new mill in 1958 approximately 2.3 mi west of the Old Rifle site (Figure 1–3). Concentrated ore was shipped to the New Rifle mill by truck and railroad from upgrading plants at Green River, Utah, and Slick Rock, Colorado (Merritt 1971). Ore for the Green River concentrator came primarily from southeast Utah; ore for the Slick Rock concentrator came from numerous mines in the Uravan Mineral Belt (DOE 1982).

Uranium and vanadium were produced at the New Rifle mill from 1958 to 1972. From 1964 to 1967, the New Rifle mill also processed lignite ash produced by Union Carbide's strip mining operations near Belfield, North Dakota. From 1973 to 1984, part of the mill was used to produce vanadium; this operation, which did not produce tailings, involved processing vanadium-bearing solutions from Union Carbide's plant at Uravan, Colorado, for various vanadium products used by the steel industry.

Uranium ore with relatively low-grade vanadium was separated in a direct acid-leaching step. Higher grade vanadium ores were initially salt roasted. AEC records document that 2,259,000 cubic yards of Old Rifle tailings and 1,802,019 tons of ore were processed. The AEC purchased 5,852 tons of uranium oxide (U_3O_8) and 2,162 tons of vanadium oxide (V_2O_5) produced by the New Rifle mill (DOE 1982).

The west central portion of the New Rifle millsite contained 33 acres of tailings and a mill area north and east of the pile. Former ponds that had held processing wastes (including vanadium and gypsum) were located east of the tailings pile. The tailings were partially stabilized with the application of mulch and fertilizer and an irrigation system was installed. However, much of the pile did not revegetate, and some of the tailings were eroded by wind and water. All tailings, contaminated materials, and associated process buildings and structures were removed from the site during the surface remedial action completed in 1996.

Organic compounds used at the New Rifle site are addressed in *Phase II Organic Investigation of Ground Water Contamination at the New Rifle Site* (DOE 1997b).

1.2.3 Target Compliance Strategy

A selection framework for determining the appropriate strategy for achieving compliance with the U.S. Environmental Protection Agency's (EPA's) ground-water protection standards is presented in the *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground-Water Project* (PEIS) (DOE 1996d). This framework was used to select the ground-water compliance strategy for the New and Old Rifle sites.

The proposed ground-water compliance strategy for both sites is (1) no remediation with application of supplemental standards, or (2) natural flushing remediation. This site-specific compliance strategy is presented in the SOWP Rev. 0 (DOE 1996e). The SOWP Rev. 0 addressed additional data needs required to determine the final site-specific compliance strategy. The recommended final compliance strategy will depend upon results of the additional characterization proposed in the following sections of this work plan and will be presented in the final SOWP Rev. 1 after completion of the field work.

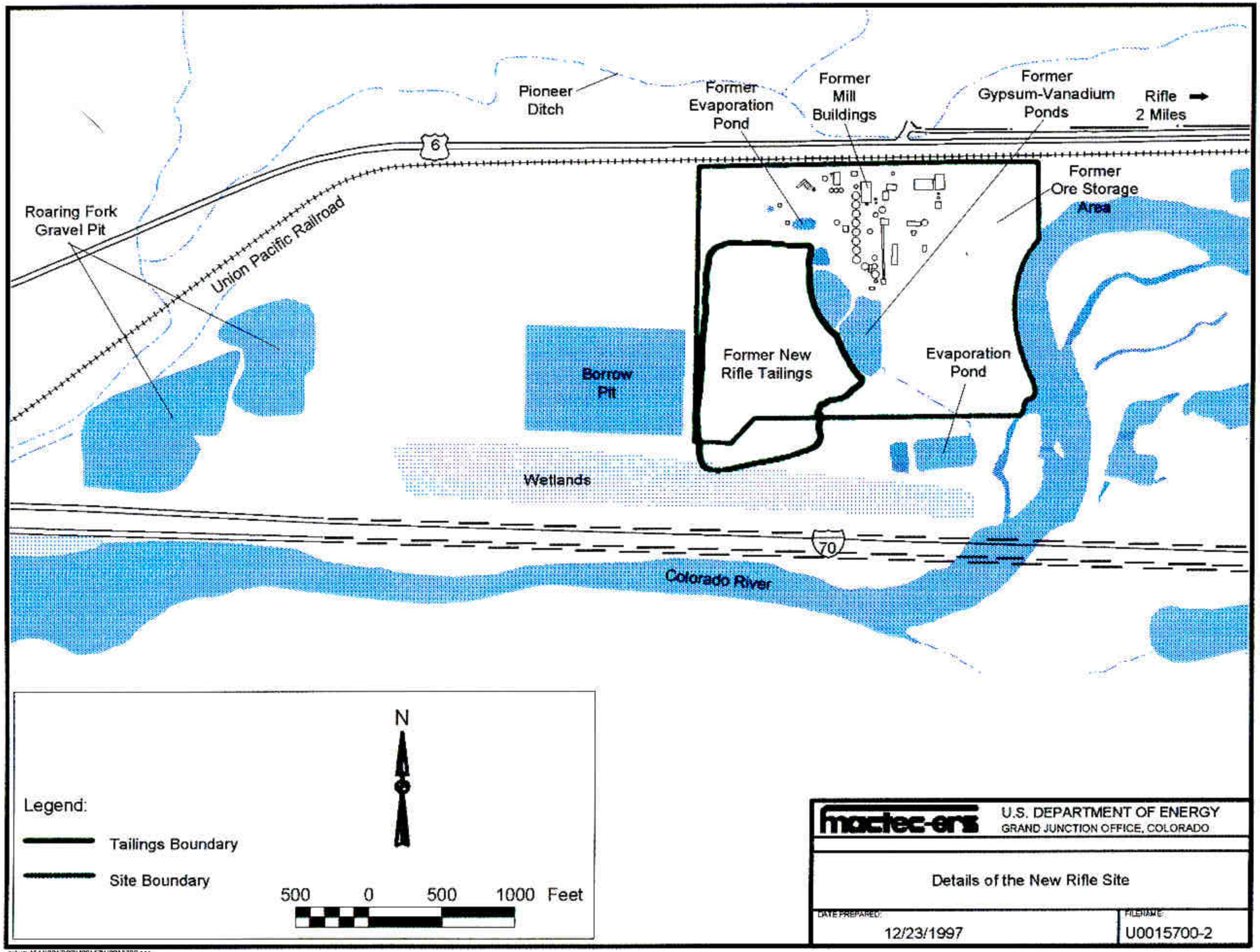


Figure 1–3. Details of the New Rifle Site

2.0 Geologic Setting

The two former Rifle millsites are located in the Colorado River Valley in northwest Colorado. Prominent topographic features near the sites are the Roan Cliffs to the northwest, the Grand Hogback monocline to the north and northeast, and the Colorado River and the northern flank of Battlement Mesa to the south. Elevations range from less than 5,300 feet (ft) above mean sea level at the river to more than 10,000 ft on Battlement Mesa.

2.1 Regional Geology

Structurally, the sites are located near the southeastern edge of the Piceance Creek basin and along the western edge of the Grand Hogback monocline that was formed in response to the adjacent White River uplift. A generalized geologic map and cross-section of the region are presented in Figures 2–1 and 2–2.

The sedimentary beds of the Wasatch Formation generally dip 5 to 10 degrees to the southwest in the vicinity of the sites. The dip steepens rapidly to 30 to 40 degrees just north of Rifle and to a near-vertical orientation along the face of the Grand Hogback monocline. Numerous faults expose Cretaceous- to Tertiary-age bedrock on the steeply dipping rock surfaces.

Directly north of the Grand Hogback and extending another 6 mi is a series of near-vertical beds of Paleozoic and Mesozoic age. In this area, one of the largest vanadium-uranium deposits on the Colorado Plateau occurs in host rocks of the Triassic Chinle Formation, Triassic-Jurassic Glen Canyon Sandstone, and Jurassic Entrada Sandstone (Chenoweth 1982, Fischer 1960). The deposits produced approximately 47 million pounds of V_2O_5 and about one million pounds of U_3O_8 were produced from the Garfield and Rifle Mines from 1925 through 1977. A few miles east of the Rifle mine several smaller vanadium-uranium deposits were mined from the Salt Wash Member of the Morrison Formation. The AEC purchased approximately 82 tons of ore from these deposits that averaged 1.79 percent V_2O_5 and 0.15 percent U_3O_8.

2.2 Local Geology

A diverse assemblage of Quaternary alluvium, colluvium, landslides, debris-flow, and loess has been mapped in and adjacent to the Colorado River valley near Rifle (Shroba et al. 1995, Stover 1993). These surficial geologic units are underlain by several thousand feet of interbedded Tertiary-age Wasatch Formation.

Both the Old and New Rifle sites rest on Quaternary floodplain alluvial deposits. These deposits consist of silt, sand, gravel, and cobbles beneath flood plains, in stream channels, and beneath terraces along the Colorado River and its major tributaries. The alluvium directly overlies several thousand feet of Wasatch Formation at both sites. The Wasatch Formation consists of variegated claystone, siltstone, sandstone, and conglomerate. Carbonaceous shale and lignite occur near the base of the formation.

2.2.1 Geology at the Old Rifle Site

Figures 2–3 and 2–4 present a generalized geologic map and a cross section extending north and south through the Old Rifle site.

The Old Rifle site is located along a low-lying alluvial terrace where a meandering channel of the Colorado River has carved a cutbank into the Wasatch Formation. The more resistant cliff-forming beds of the Wasatch Formation are exposed directly west and north of the site (Figure 2–3). Lateral accretion of the meander deposited a uniform thickness of approximately 20 ft of floodplain alluvium, which is bounded on the cutbank side by the Wasatch Formation and on the river side to the south by a terrace scarp. The floodplain alluvium consists of unweathered, well-rounded clasts that range in size from cobbles to clay.

Shroba and others (1995) and Stover (1993) mapped an older alluvial terrace unit resting on the exposed bedrock of the Wasatch Formation at the site. The lower part of the unit was deposited by the Colorado River and generally consists of poorly to moderately well-sorted, clast-supported, cobbly pebble gravel with a sand matrix. The unit contains subrounded to well-rounded igneous, metamorphic, and sandstone clasts.

Springs flow along the contact between the older alluvial terrace gravels and the underlying, relatively impermeable Wasatch Formation. Surface runoff from the seeps is collected in an unlined irrigation ditch that parallels U.S. Highway 6 above the site. A culvert under U.S. Highway 6 discharges the runoff to the center of the site.

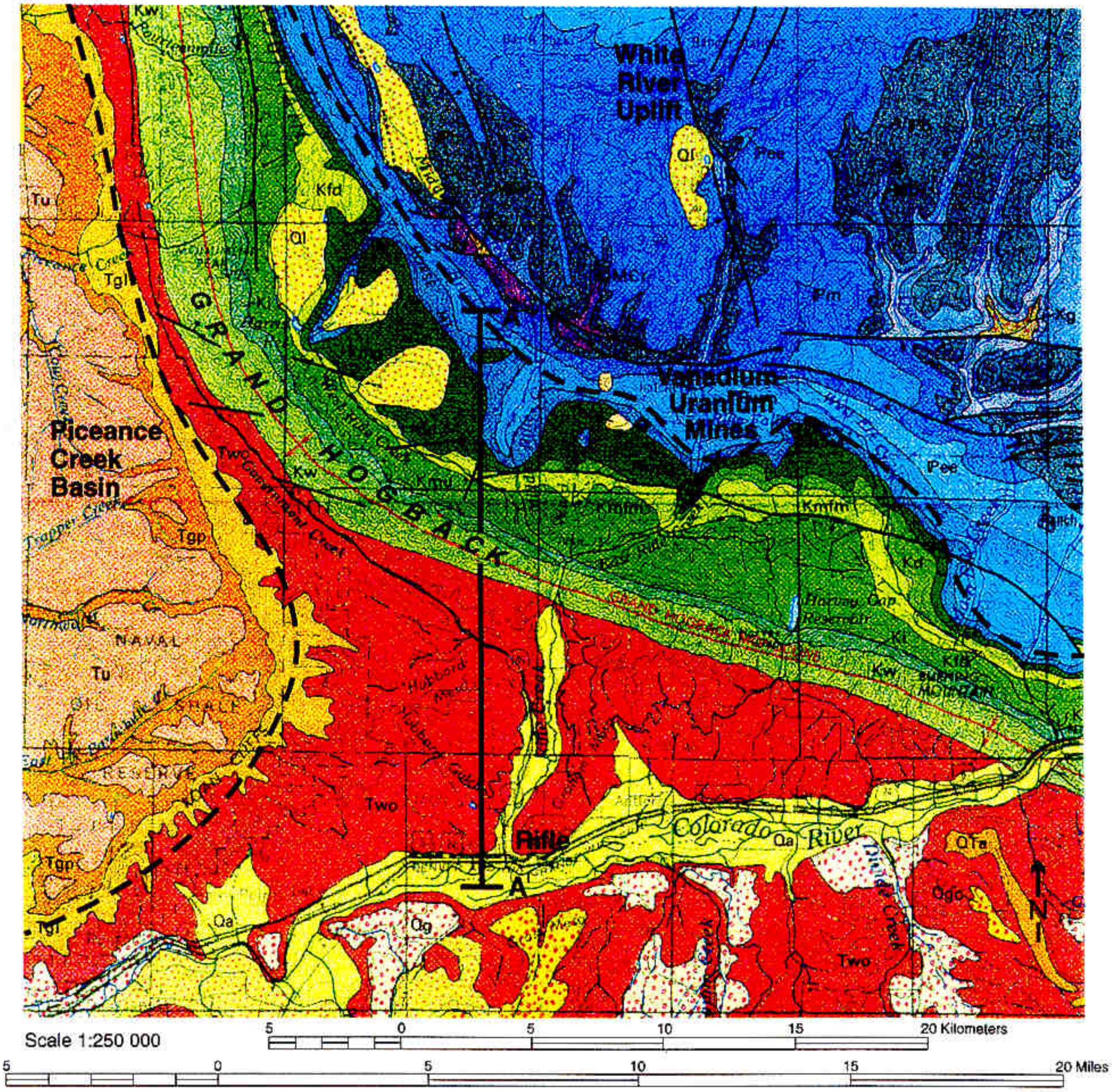
2.2.2 Geology at the New Rifle Site

A generalized geologic map and a cross section extending north and south through the New Rifle site are presented in Figures 2–5 and 2–6, respectively.

Most of the New Rifle site is located on a broad section of Colorado River floodplain alluvium deposited over the Wasatch Formation (Figure 2–6). The alluvium thickness at the New Rifle site ranges from about 20 to 25 ft in the vicinity of the former tailings pile to about 18 to 20 ft at the Roaring Fork gravel pit approximately 0.5 mi west of the site. Slightly more than 1 mi west of the site the alluvium thickens to more than 40 ft.

Alluvial fan material deposited by small intermittent streams covers the northernmost portion of the site and extends north across U.S. Highway 6 to where the Wasatch Formation crops out (Shroba et al. 1995). The alluvial fan unit is mostly poorly sorted, poorly stratified, clast- and matrix-supported, slightly bouldery, cobbly pebble gravel with a silty sand matrix. The unit probably grades vertically and laterally to the north into Wasatch colluvium.

Deposits of older alluvial gravels, sheetwash, and loess cover portions of the Wasatch Formation immediately north of the New Rifle site.



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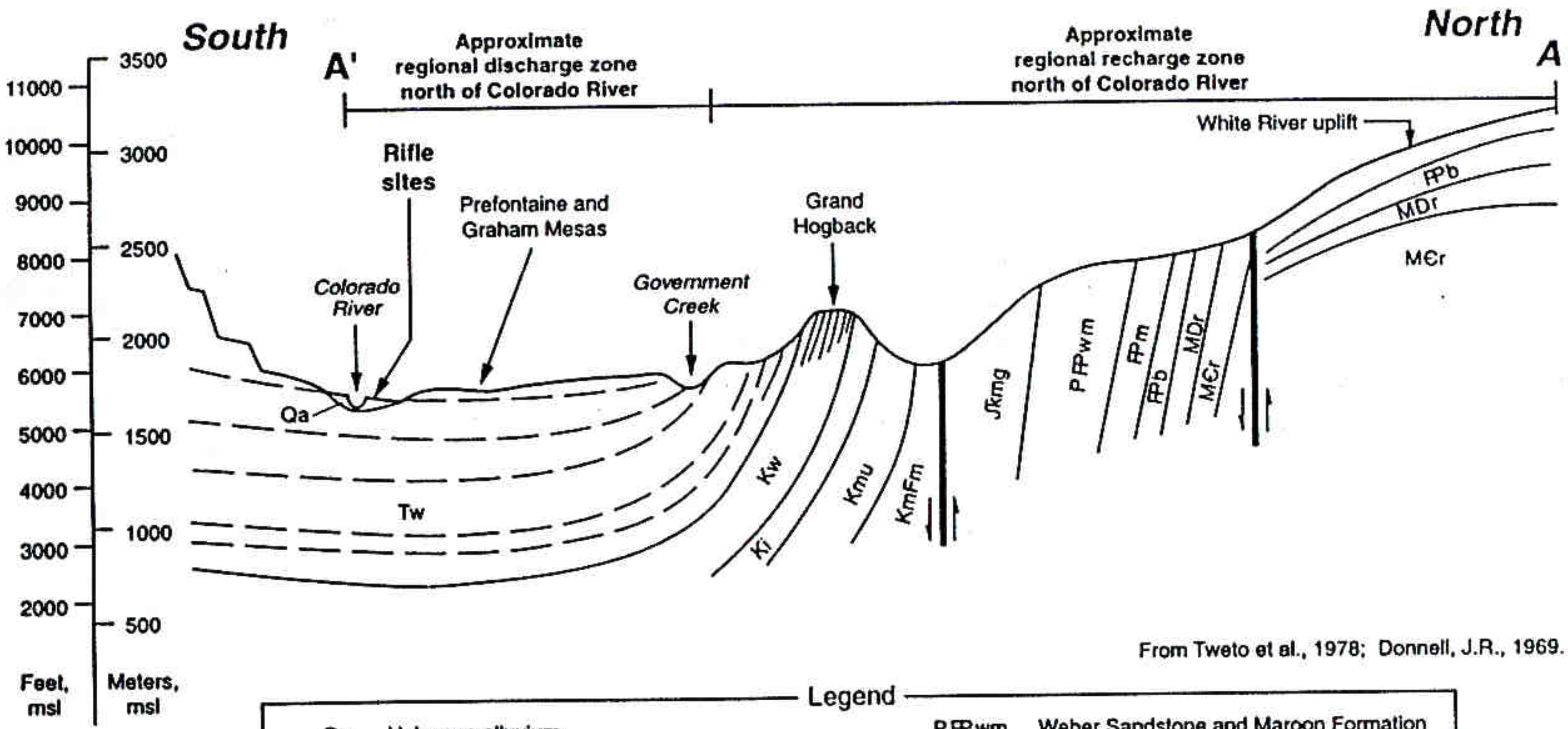
- **Qa** Unconsolidated deposits (Holocene): Alluvium
- **Qg** Unconsolidated deposits (Pleistocene) young gravels (Bull Lake and younger)
- **Qta** High-Level Alluvium (Pleistocene and/or Pliocene)
- **Tbp** Browns Park Formation (Miocene)
- **Tu** Uinta Formation (Eocene)
- **Tgp** Parachute Creek Member (Eocene)
- **Tgl** Lower part of Green River Formation (Eocene)
- **Two** Wasatch and Ohio Creek Formations (Eocene and Paleocene)
- **Kw** Williams Fork Formation (Upper Cretaceous)
- **Ki** Iles Formation (Upper Cretaceous)
- **Kmu** Upper unit of Mancos Shale (Upper Cretaceous)
- **Kmfm** Frontier Sandstone and Mowry Shale Members and intervening shale zone (Upper and Lower Cretaceous)
- **Kd** Dakota Sandstone (Lower Cretaceous)
- **Kfd** Frontier Sandstone and Mowry Shale Members of Mancos Shale and Dakota Sandstone (Lower Cretaceous)
- **Jbmg** Morrison, Entrada, and Glen Canyon Formations (Upper Jurassic to Upper Triassic)
- **Pm** Minturn Formation (Pennsylvanian)
- Belden Formation (Pennsylvanian)
- **M€r** Mississippian, Devonian, Ordovician, and Cambrian Rocks

Figure 2–1. Regional Geologic Map of the Rifle Area



Legend

Qa	Holocene alluvium	PPwm	Weber Sandstone and Maroon Formation
Tw	Wasatch Formation	Pm	Minturn Formation
Kw	Williams Fork Formation Mesaverde Group	Pb	Belden Formation
Ki	Iles Formation, Mesaverde Group	MDr	Mississippian and Devonian Rock
Kmu	Upper unit of Mancos Shale	MЄr	Mississippian and Cambrian Rock
KmFm	Frontier Sandstone and Mowry Shale Member of Mancos Shale	///	Fault/fracture zone
Jkmg	Morrison, Entrada, and Glen Canyon Formations	— —	Estimated dip of bedding

Figure 2–2. Generalized Regional Geologic Cross-Section, Rifle Sites

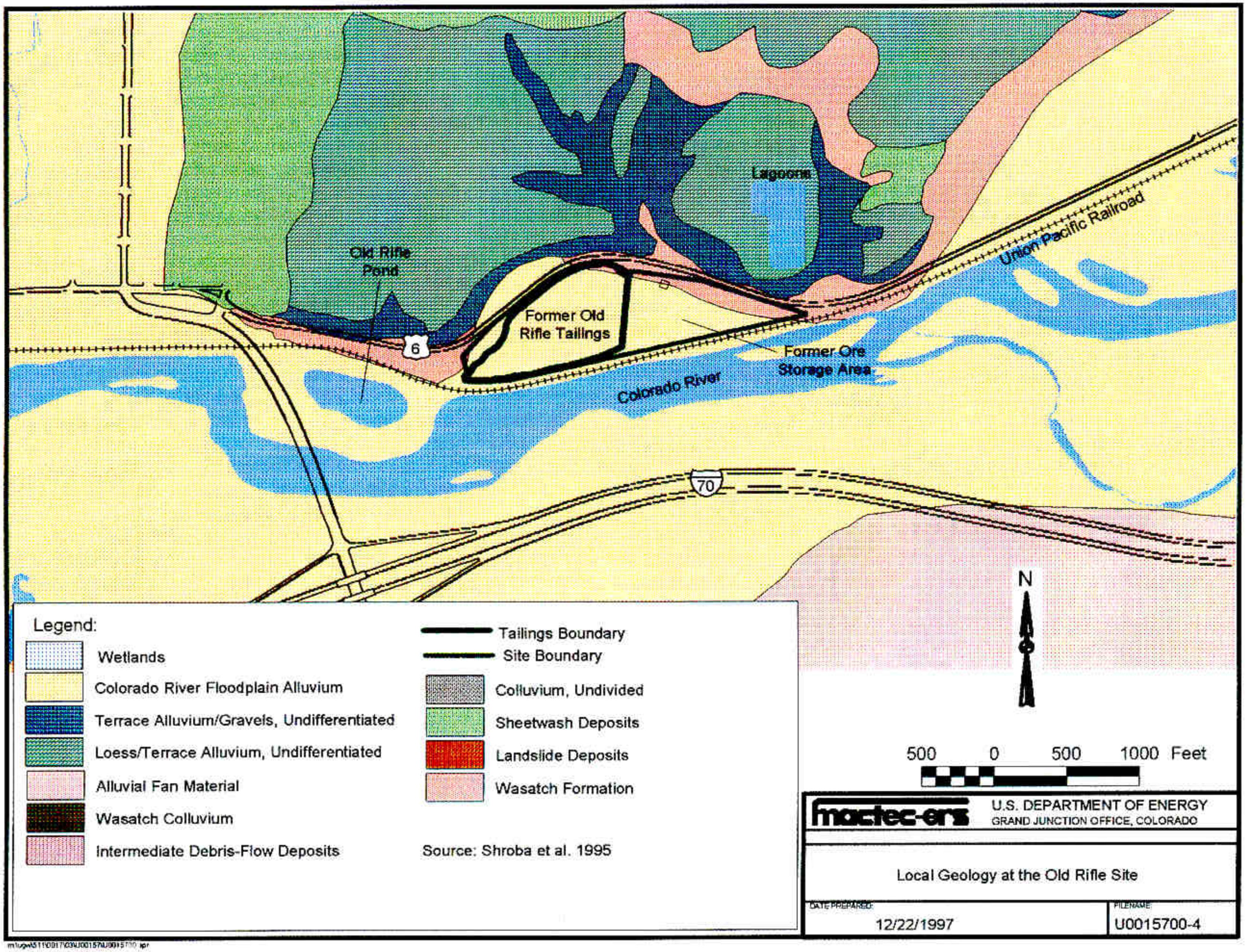


Figure 2–3. Local Geology at the Old Rifle Site

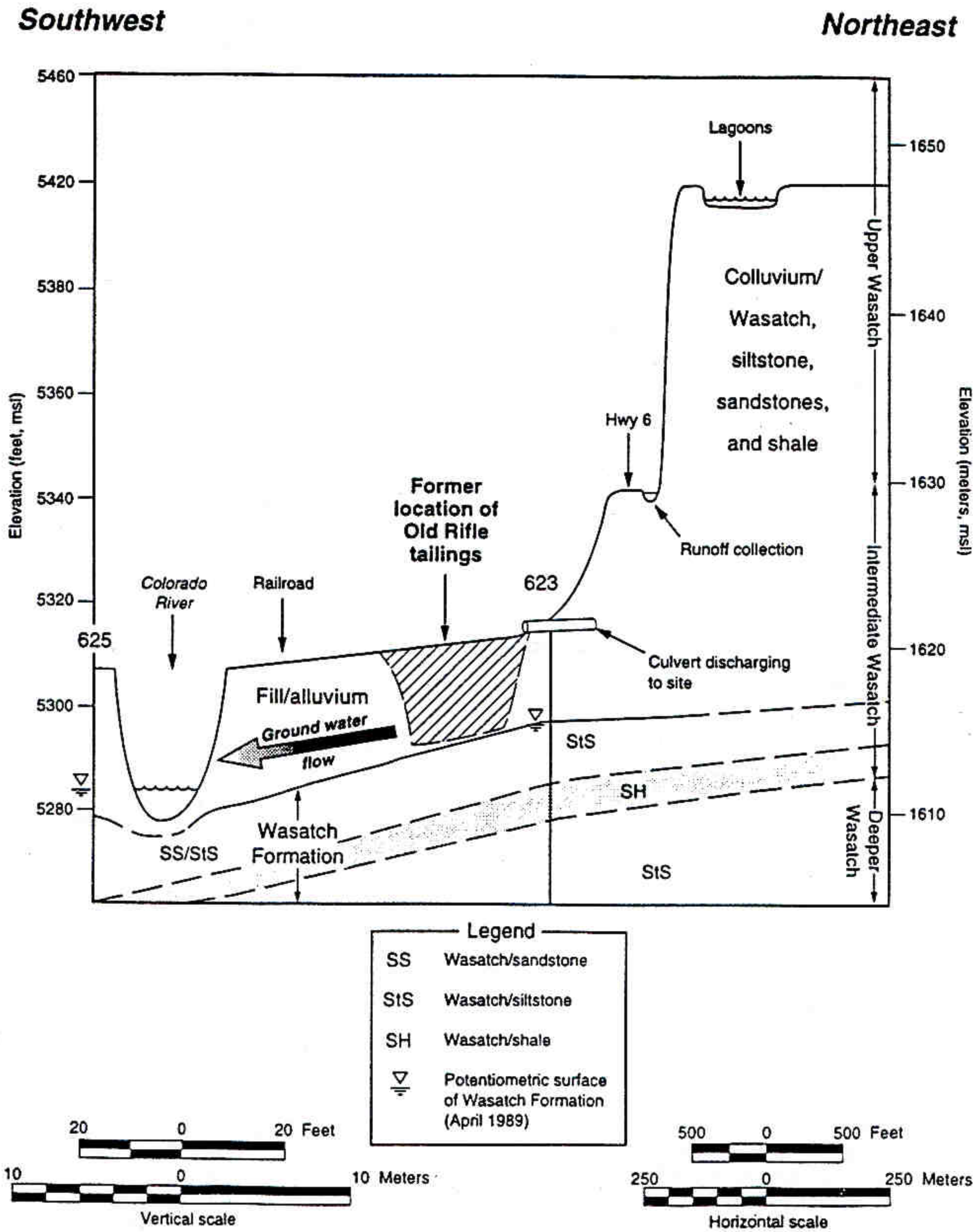


Figure 2–4. Generalized Geologic Cross Section , Old Rifle Site

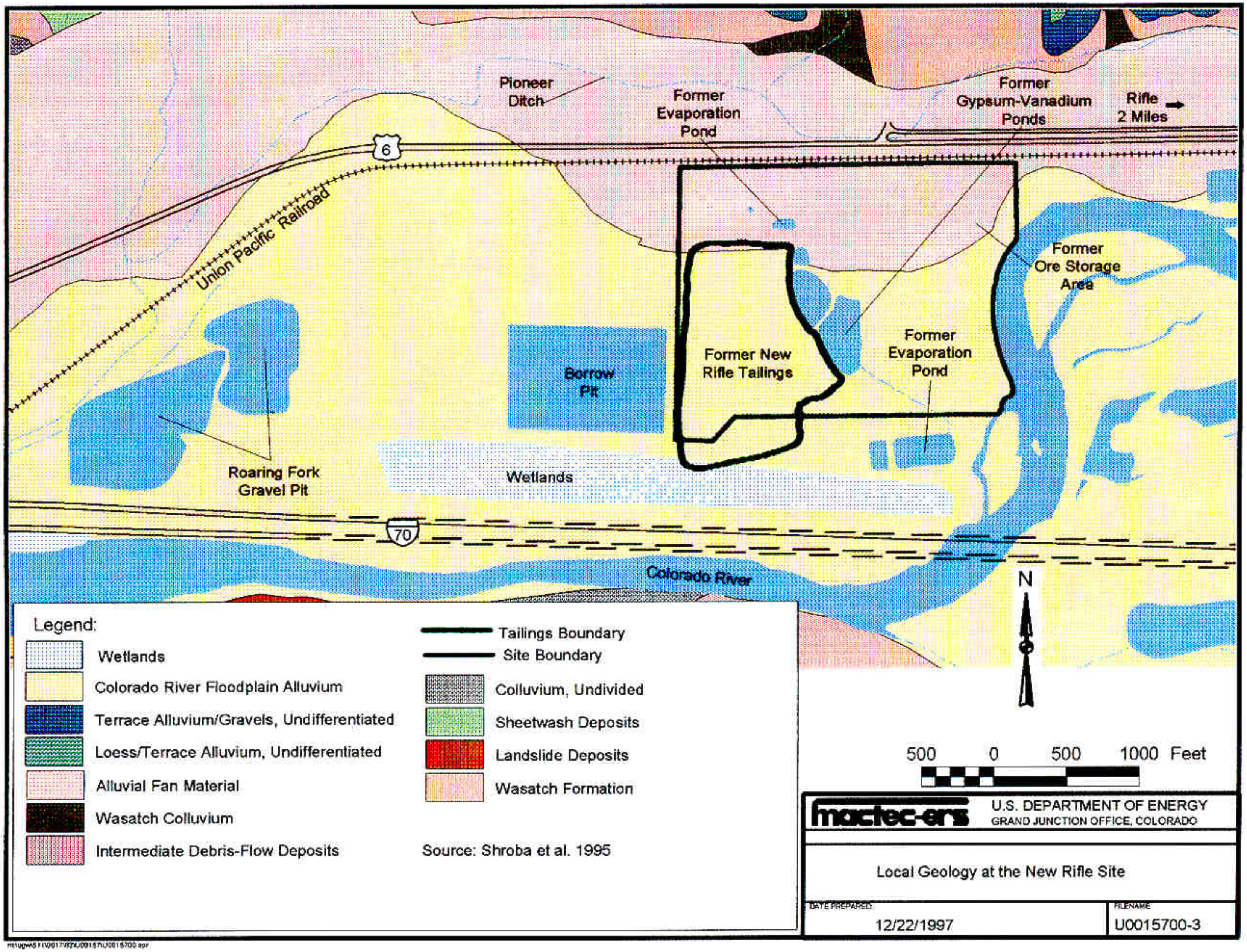


Figure 2–5. Local Geology at the New Rifle Site

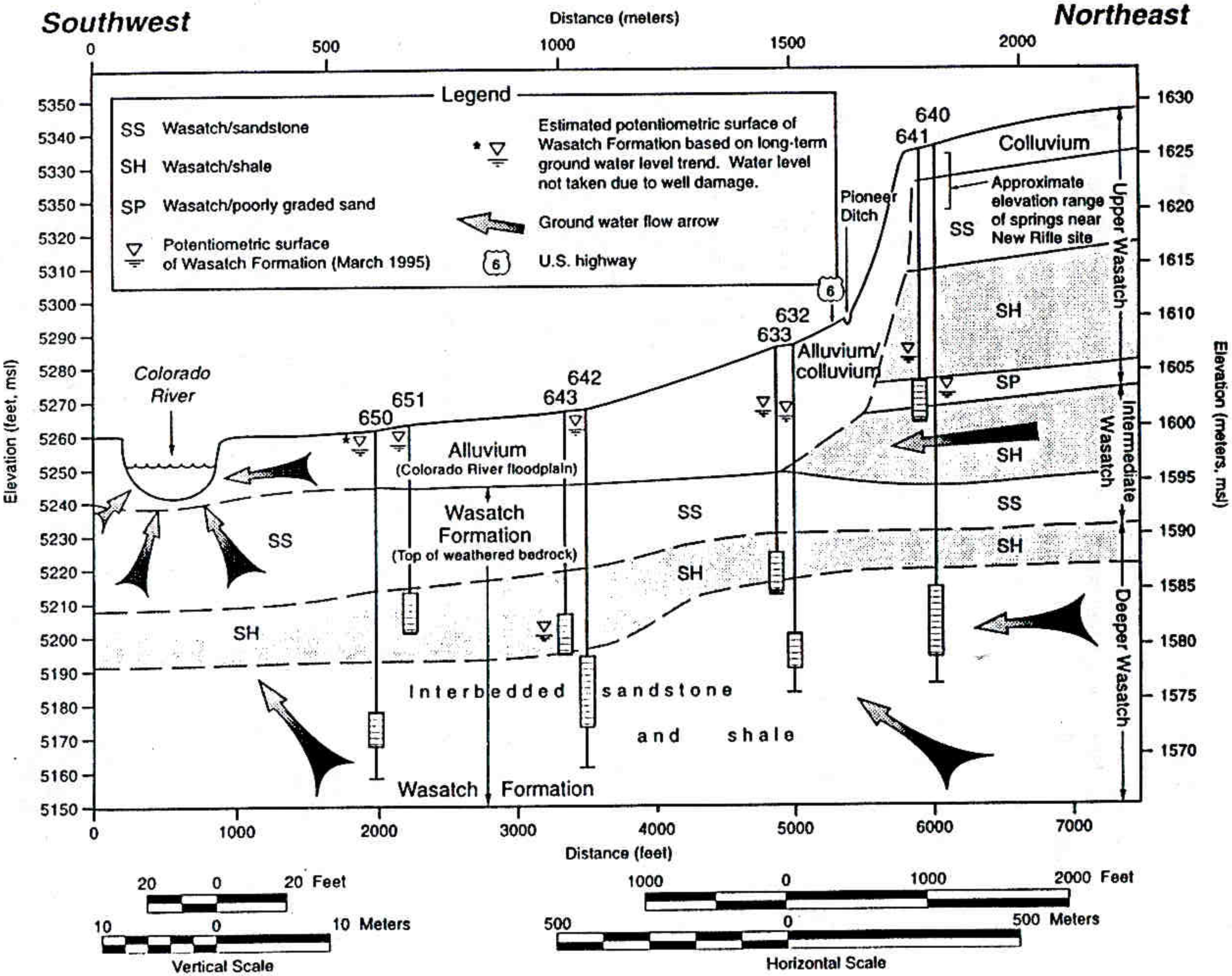


Figure 2–6. Generalized Geologic Cross Section, New Rifle Site

The upper part of the older alluvial terrace gravels on Graham Mesa north of the site was deposited by a former course of Rifle Creek and consists of slightly silty to silty sand with occasional thin, well-sorted, pebble and sand lenses. The upper fine-grained alluvium on Graham Mesa is mantled by loess.

2.3 Summary of Data Needs

Additional geologic mapping is required to (1) verify local geologic contacts, (2) assist in the interpretation of subsurface geology and ground-water flow relationships, and (3) refine the site conceptual model of each site.

3.0 Hydrogeology

The major components of the hydrologic system at the Rifle sites include the Colorado River, unsaturated alluvial sediments, saturated alluvial and colluvial sediments, and saturated siltstone, shale, and sandstone of the Wasatch Formation. The saturated alluvial and colluvial sediments, together with sporadic occurrences of weathered Wasatch Formation materials, form the unconfined alluvial aquifer. Competent rock of the Wasatch Formation underlies the unconsolidated deposits of the alluvial aquifer. Lithologic logs from existing wells suggest that low-permeability shales and siltstones of the Wasatch Formation separate the unconsolidated alluvium, colluvium, and weathered Wasatch Formation materials of the alluvial aquifer from the more permeable sandstones of the Wasatch Formation aquifer. However, the aquitard formed by the shale and siltstone units within the upper Wasatch Formation has not yet been rigorously mapped.

Previous data indicate that the majority of the contamination derived from past milling activities and tailings storage is limited to the alluvial aquifer, although some contamination has been detected in the upper portions of the Wasatch Formation at the New Rifle site (DOE 1996e).

3.1 Surface-Water Hydrology

3.1.1 Old Rifle Site

At the Old Rifle site, surface-water features include the Colorado River, Old Rifle pond, an unnamed drainage ditch extending north to south across the center of the site, surface runoff ditches located above the site on the north side of Highway 6, and detention lagoons used by the City of Rifle and located above the Old Rifle site on Graham Mesa. The Colorado River forms the southern boundary of the Old Rifle site and is the dominant surface-water feature, ultimately receiving all surface drainage from the vicinity of the Old Rifle site. The river also receives baseflow ground-water discharge from the alluvial aquifer at the Old Rifle site during periods of low river flow that extend from July or August through February or March. During periods of spring runoff between March and June, high river flows exceed ground-water elevations in the alluvial aquifer, and the Colorado River is temporarily a recharge source for at least the southern portion of the Old Rifle site. Fluctuations in river stage are expected to produce a significant response in ground-water elevations near the river; aquifer response would diminish with increasing distance from the river, although this relationship has not yet been quantified.

Precipitation falling on the site drains south, directly into the river and also into the unnamed ditch that extends north to south and discharges into the river. In addition to precipitation runoff directly from the site, this ditch receives surface drainage from along and above Highway 6 via an underground culvert beneath the highway. The culvert empties directly into the north end of the ditch; estimated discharge ranges from 20 to 50 gallons per minute (DOE 1996e). Depending on ground-water levels and runoff volumes, the ditch likely acts as both a recharge source and a discharge area for ground water beneath the Old Rifle site. Surface drainage on the north side of Highway 6 is routed to the culvert and the unnamed ditch via an unlined ditch on the north side of the highway. Infiltration from this ditch contributes to recharge of the alluvial aquifer in the vicinity of the highway.

Immediately north of Highway 6 is Graham Mesa, a relict river terrace consisting of a thin mantle of alluvial and colluvial deposits on eroded Wasatch Formation bedrock. As part of its water supply system, the Rifle Municipal Water Department has operated several lagoons on Graham Mesa just north and east of the site. These unlined ponds have been used as settling basins for Colorado River backwash water containing high concentrations of sediment. Infiltration from the ponds enters alluvial and colluvial sediments north of Highway 6 and then either discharges as seeps along the alluvium/Wasatch contact at that point or recharges the topographically elevated bedrock of the Wasatch Formation. A recent site inspection could not confirm that these lagoons are still in place, although it is possible that they were simply not located during the tour. The presence or absence of the lagoons will be confirmed on a future site visit.

3.1.2 New Rifle Site

At the New Rifle site, surface-water features include the Colorado River, the Roaring Fork gravel pit, the mitigation wetlands, a borrow pit intermittent pond, the Pioneer irrigation ditch, and wastewater treatment ponds. The Colorado River forms the southern boundary of the New Rifle site and is the dominant surface-water feature, receiving surface drainage from the vicinity of the New Rifle site and baseflow ground-water discharge from the alluvial aquifer along the southern portion of the site during periods of low river flows that extend from July or August through February or March. During periods of spring runoff between March and June, high river flows exceed ground-water elevations in the alluvial aquifer and the Colorado River is temporarily a recharge source for the southern portion of the New Rifle site. It is likely that the north-south reach of the river east of the site is a ground-water recharge source throughout most of the year. Fluctuations in river stage are expected to produce a significant response in ground-water elevations near the river; aquifer response would diminish with increasing distance from the river, although this relationship has not yet been quantified.

The Roaring Fork gravel pit is located west of the New Rifle site and consists of two large excavations. Gravel is currently being removed from the eastern pit, which has been excavated to bedrock. Because the pit now intersects the alluvial water table, the pit has filled with ground water. To facilitate ongoing operations, water is intermittently pumped from the east pit into the west pit, where a perennial pond has formed. This process has created a situation in which ground water flows into the east pit where it is pumped into the west pit from which it infiltrates back into the alluvial aquifer. Some of the ground-water recharge emanating from the pond in the west pit ultimately recirculates back into the east pit where it is then pumped into the pond again. Most of the recharge emanating from the west pit simply returns to the alluvial aquifer and continues a southwesterly flow. Because the east pit is effectively behaving as a large-diameter pumping well located next to a large diameter downgradient recharge well, it likely has the net effect of increasing hydraulic gradients east of the pit. Such an increase will be accompanied by an increase in ground-water flow velocities east of the pit and a warping of flow directions towards the pit in areas to the north and south.

The mitigation wetlands are located along the southern edge of the site, north of the interstate and the Colorado River. The wetlands were constructed during remedial action to replace natural wetlands lost over the course of milling and remedial action activities. The wetlands are constructed to intersect the water table in the alluvial aquifer during the high-water period of

May and June. During this period, evapotranspiration from the wetlands causes ground-water discharge to the wetlands, although this discharge is not likely to measurably alter ground-water flow directions in the alluvial aquifer. During other periods of the year, the wetlands act as a ground-water discharge area through the process of plant transpiration. This discharge is also likely to be insignificant.

Pioneer ditch, located north of the site and Highway 6, is an unlined irrigation ditch distributing water diverted from Rifle Creek. The ditch is constructed in alluvial and colluvial deposits just south of the Wasatch outcrop that forms the northern limit of the alluvial aquifer. Leakage from the ditch recharges the alluvial aquifer and flows southwest. The significance of the recharge from Pioneer ditch will be explored by monitoring water levels in wells near the ditch to examine changes in water levels that can be correlated to flowing and dry conditions in the ditch.

Several wastewater treatment ponds are located east of the site in a narrow section of the alluvial aquifer bounded by Wasatch Formation outcrop to the north and the Colorado River to the south. The ponds are used as part of the City of Rifle wastewater treatment system. It is unknown at this time if the ponds are lined or unlined. Any leakage from the ponds could influence site hydrogeology, including water levels and water quality.

3.2 Alluvial Aquifer

3.2.1 Old Rifle Site

The alluvial aquifer is the uppermost hydrogeologic unit at the Old Rifle site. The alluvial aquifer is composed of unconsolidated alluvial and colluvial deposits that include clays, silts, sands, gravels, and cobbles. The unconsolidated sediments of the alluvial aquifer overlie the Wasatch Formation. In general, colluvial sediments eroded from Wasatch Formation outcrops tend to be coarser than the alluvial terrace and floodplain deposits derived from fluvial action of the Colorado River. Colluvial deposits commonly underlie the Colorado River terrace and floodplain deposits and are also found more frequently along the northern sections of the site near Wasatch outcrops. Colluvial deposits tend to have a greater coarse-grained fraction than alluvial deposits. Alluvial floodplain and terrace deposits tend to show an increasing coarse-grained fraction with increasing depth and proximity to the river. Underlying the unconsolidated deposits are irregularly distributed sections of weathered Wasatch Formation that appear to be hydraulically connected to and of similar hydraulic characteristics as the unconsolidated sediments. The distribution and characteristics of weathered Wasatch Formation materials have not been well documented.

The extent of the alluvial aquifer at the Old Rifle site is largely limited to the site boundary; narrow sections of alluvium extend eastward between the river and the Wasatch outcrop and westward past a prominent Wasatch outcrop toward Old Rifle pond (Figure 1–2).

Thickness of the alluvial/colluvial deposits at the Old Rifle site is approximately 20 to 25 ft over most of the site. Depths to ground water range from 10 to 17 ft on the site and from 3 to 8 ft east and west of the site near the river. Saturated thickness ranges from 4 to 18 ft in the vicinity of the Old Rifle site.

Recharge to the alluvial aquifer at the Old Rifle site occurs as infiltration of precipitation, leakage from drainage ditches north of Highway 6 and from the unnamed ditch extending north to south across the site, and discharge from the Colorado River that probably occurs only during high water stages in late spring and early summer. Hydraulic gradients indicate that movement between the Wasatch Formation and the alluvial aquifer may also contribute recharge to the alluvial aquifer. This condition has been documented at the New Rifle site (DOE 1996e) and may also exist at the Old Rifle site, but has not yet been confirmed. Some recharge also likely occurs as horizontal discharge of ground water from the steep face of the Wasatch Formation directly into the alluvial ground-water system. If occurring, this process would be found along the steep Wasatch subcrop that forms the northern boundary of the alluvial aquifer along Highway 6.

Baseflow to the Colorado River during low-water periods constitutes the main mechanism of discharge from the alluvial aquifer at the Old Rifle site. Plant transpiration in areas of shallow ground-water depths and discharge to Old Rifle pond followed by evaporation are the only other processes by which ground water is discharged from the alluvial aquifer.

Hydraulic conductivities estimated from slug test data range from 0.13 to 2.1 ft/day (DOE 1996e). These values are in the low end of the range for sands and gravels and may underestimate actual conductivities. Hydraulic gradients, directed west-southwest (Figure 3–1), are approximately 0.0045 ft/ft. Average linear velocities based on these estimates and an assumed porosity of 0.3 range from 0.7 to 11 ft/year.

3.2.2 New Rifle Site

The alluvial aquifer is the uppermost hydrogeologic unit at the New Rifle site. The alluvial aquifer is composed of unconsolidated alluvial and colluvial deposits that include clays, silts, sands, gravels, and cobbles. The unconsolidated sediments of the alluvial aquifer overlie the Wasatch Formation. As at the Old Rifle site, colluvial sediments eroded from Wasatch Formation outcrops tend to be coarser than the alluvial terrace and floodplain deposits derived from fluvial action of the Colorado River. Colluvial deposits commonly underlie the Colorado River terrace and floodplain deposits and are also found more frequently along the northern sections of the site near Wasatch outcrops. Colluvial deposits tend to have a greater coarse-grained fraction than alluvial deposits. Alluvial floodplain and terrace deposits show increasing coarse-grained fractions with increasing depth and proximity to the river. Underlying the unconsolidated deposits are irregularly distributed sections of weathered Wasatch Formation that appear to be hydraulically connected to and of similar hydraulic characteristics as the unconsolidated sediments. These weathered sections of the Wasatch Formation have been referred to previously as both the weathered Wasatch Formation or the intermediate Wasatch Formation. Although the Wasatch Formation has been better characterized at the New Rifle site than it has at the Old Rifle site, the characteristics of weathered Wasatch Formation materials have not been well documented. As at the Old Rifle site, the weathered Wasatch Formation at the New Rifle site is regarded as part of the alluvial flow system. The alluvial flow system at

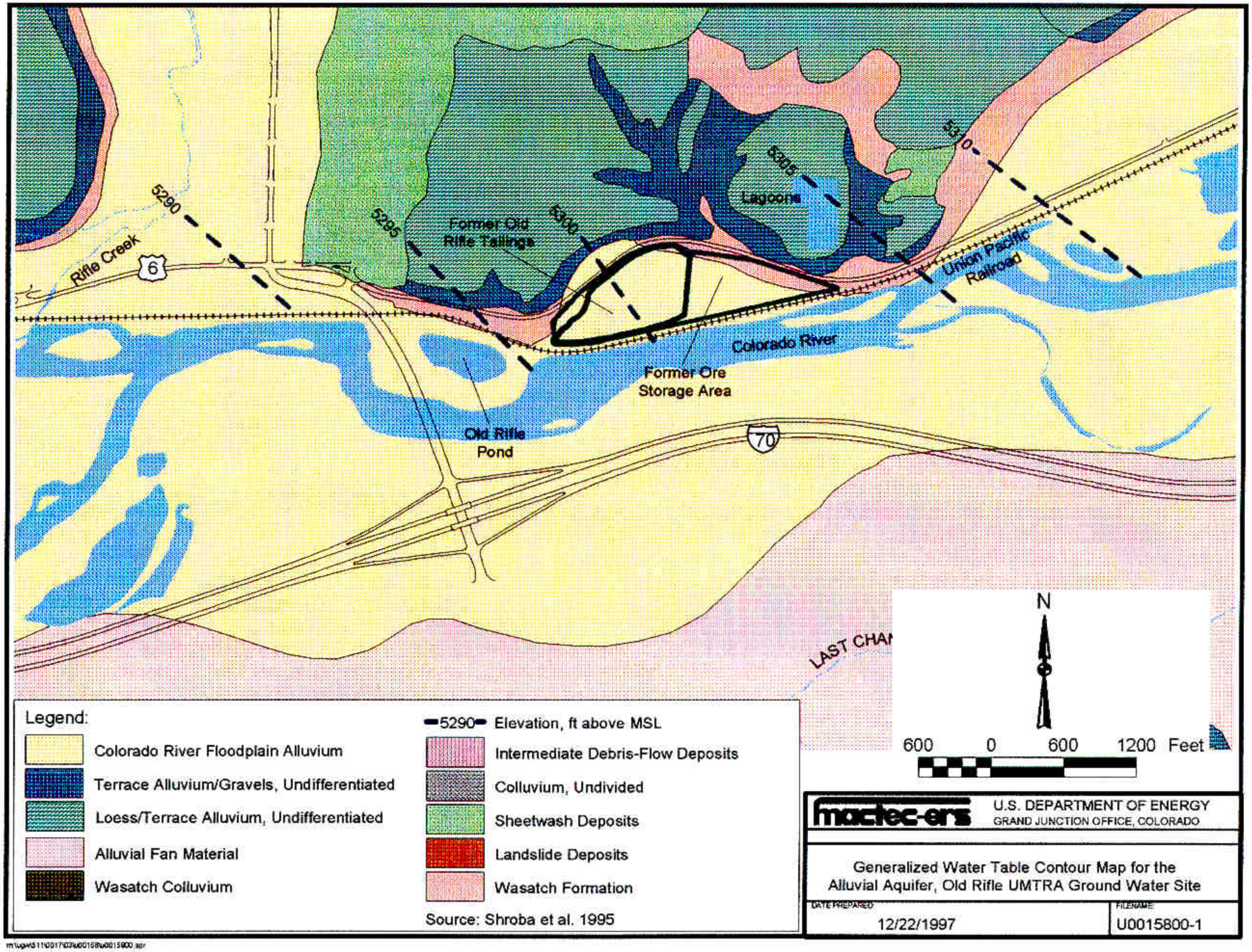


Figure 3–1. Generalized Water Table Contour Map for the Alluvial Aquifer, Old Rifle UMTRA Ground Water Site

the New Rifle site will be investigated as a modestly stratified aquifer, of which the uppermost stratum consists of saturated, predominantly fine-grained alluvial floodplain deposits largely composed of clays, silts, and fine-grained sands; the underlying stratum consists largely of saturated colluvial deposits (clayey/silty sands, gravels, cobbles, and colluvial blocks) along the northern sections of the alluvial aquifer, and coarse-grained fluvial deposits along the southern section near the Colorado River.

The alluvial aquifer at the New Rifle site extends north of Highway 6 to the east-west trending outcrop of the Wasatch Formation, south to the Colorado River, and east to the City of Rifle. Actual pinching out of the alluvial aquifer by intersecting Wasatch Formation and Colorado River segments has not been documented, but the horizontal extent of the aquifer at those locations is so limited that it is regarded as absent. The western limit of the alluvial aquifer has not been defined; however, the aquifer is known to be present well beyond the westernmost area of interest.

Thickness of the alluvial/colluvial deposits at the New Rifle site ranges from less than 20 ft to more than 80 ft. The shallowest deposits are along the river and in the vicinity of Roaring Fork gravel pit. Greatest thicknesses are found north of the freeway interchange west of the site. Depths to ground water range from less than 3 ft to more than 60 ft; the shallow depths are east of the site near the river and the greater depths are in the areas of thick alluvial deposits west of Roaring Fork gravel pit. Saturated thicknesses generally range from 10 to 20 ft near the New Rifle site.

Recharge to the alluvial aquifer at the New Rifle site occurs as infiltration of precipitation, leakage from the Pioneer ditch north of Highway 6, possible leakage from the wastewater treatment ponds east of the site, and discharge from the Colorado River. Comparison of ground-water elevations and river stages near the north-south reach of the river east of the site suggest that this reach may be recharging the aquifer throughout much of the year. Recharge to the aquifer from the remainder of the river in the vicinity of the site likely occurs only during the high river stage in May and June. The influence of this transient recharge extends a limited distance northward from the river. Vertically upward hydraulic gradients between the Wasatch Formation and the alluvial aquifer also contribute recharge to the alluvial aquifer in some areas. Some recharge also likely occurs as horizontal discharge of ground water from the steep face of the Wasatch Formation directly into the alluvial ground-water system. If occurring, this process would be found along the steep Wasatch subcrop that forms the northern boundary of the alluvial aquifer north of Highway 6.

Discharge from the alluvial aquifer occurs as baseflow to the east-west reach of the Colorado River (except during the high-stage period in May and June), discharge to the Roaring Fork gravel pit and the mitigation wetlands followed by evapotranspiration, and limited plant transpiration in areas of shallow ground-water depths.

Hydraulic conductivities estimated from slug test data range from 0.22 to 1.7 ft/day (DOE 1996e). These values are in the low end of the range for sands and gravels and may underestimate actual conductivities. The hydraulic gradient, directed west-southwest (Figure 3–2), averages approximately 0.0042 ft/ft. Average linear velocities based on these estimates and an assumed porosity of 0.3 range from 1 to 9 ft/year.

3.3 Wasatch Formation

3.3.1 Old Rifle Site

The Wasatch Formation is composed of interbedded siltstone, shale, and sandstone; the siltstone and shale units form aquitards and the underlying sandstone units form an aquifer or series of aquifers with semiconfined to confined characteristics. Although not well documented at the Old Rifle site, the uppermost 3 to 5 ft of the Wasatch Formation appears to be weathered in many areas and hydraulically well connected to the overlying saturated alluvial/colluvial deposits. This interpretation is based largely on data from borings at the New Rifle site, but is likely representative of conditions at the Old Rifle site as well. Some lithologic logs for previously installed wells at both the New and Old Rifle sites show sandstone or a combination of sandstone with shale or siltstone as the first unit encountered when drilling through the Wasatch. However, the majority of the data suggest that in the vicinity of the Old Rifle site, the Wasatch is a stratified hydrogeologic unit consisting of 3 to 5 ft of weathered shale, siltstone, and occasionally sandstone underlain by up to 80 ft of competent siltstone and shale that forms an aquitard. Underlying this aquitard is a saturated, semiconfined to confined sandstone aquifer of undetermined thickness. The lithologic logs supporting this conceptual model were prepared while logging cuttings discharged during mud and air rotary drilling, and as such are of limited integrity.

Depth to the top of the Wasatch Formation at the Old Rifle site is about 20 to 30 ft; the contact surface dips gently to the south. Depth to water typically ranges from 3 to 15 ft below ground surface; three wells show depths to water of 30, 72, and 85 ft. Of the Wasatch Formation wells installed near the Old Rifle site, only two (wells 623 and 624) were actually installed on site. The water level in well 624 is within 2 ft of the bottom of the well and is 57 ft deeper than the water level in well 623, which is immediately adjacent to well 624. These facts make the water level in well 624 questionable. The alluvial well nearest to well 623 is well 584, approximately 200 ft south. Ground-water elevation in well 584 is approximately 3.5 ft higher than in Wasatch well 623. The only paired alluvial and Wasatch wells near the Old Rifle site are alluvial wells 597/598 and Wasatch well 620. Water levels in all three wells are approximately 5,311 ft above datum, which suggests little or no vertical gradient. Wasatch well 620 is screened in a relatively shallow section of the Wasatch Formation (30 to more than 50 ft). This group of wells therefore represents the hydraulic relationship between the alluvium and the section of the Wasatch Formation that is most susceptible to vertical contaminant invasion and reveals little or no driving force for downward contaminant migration.

Recharge to the Wasatch Formation occurs mainly as precipitation falling directly on the outcrop to the north in the vicinity of the Grand Hogback. Discharge reportedly occurs mainly as upward leakage through the alluvial aquifer to the Colorado River (DOE 1996e), although this interpretation is not based on site-specific data.

Hydraulic conductivity estimates from slug tests conducted on wells 621 and 622 were 0.01 and 0.03 ft/day (DOE 1996e). Horizontal hydraulic gradients in the Wasatch Formation are to the southwest (Figure 3–3) and average 0.003 ft/ft (DOE 1996e). Assuming a porosity of 0.15, the average linear velocity in the Wasatch Formation is approximately 0.15 ft/year.

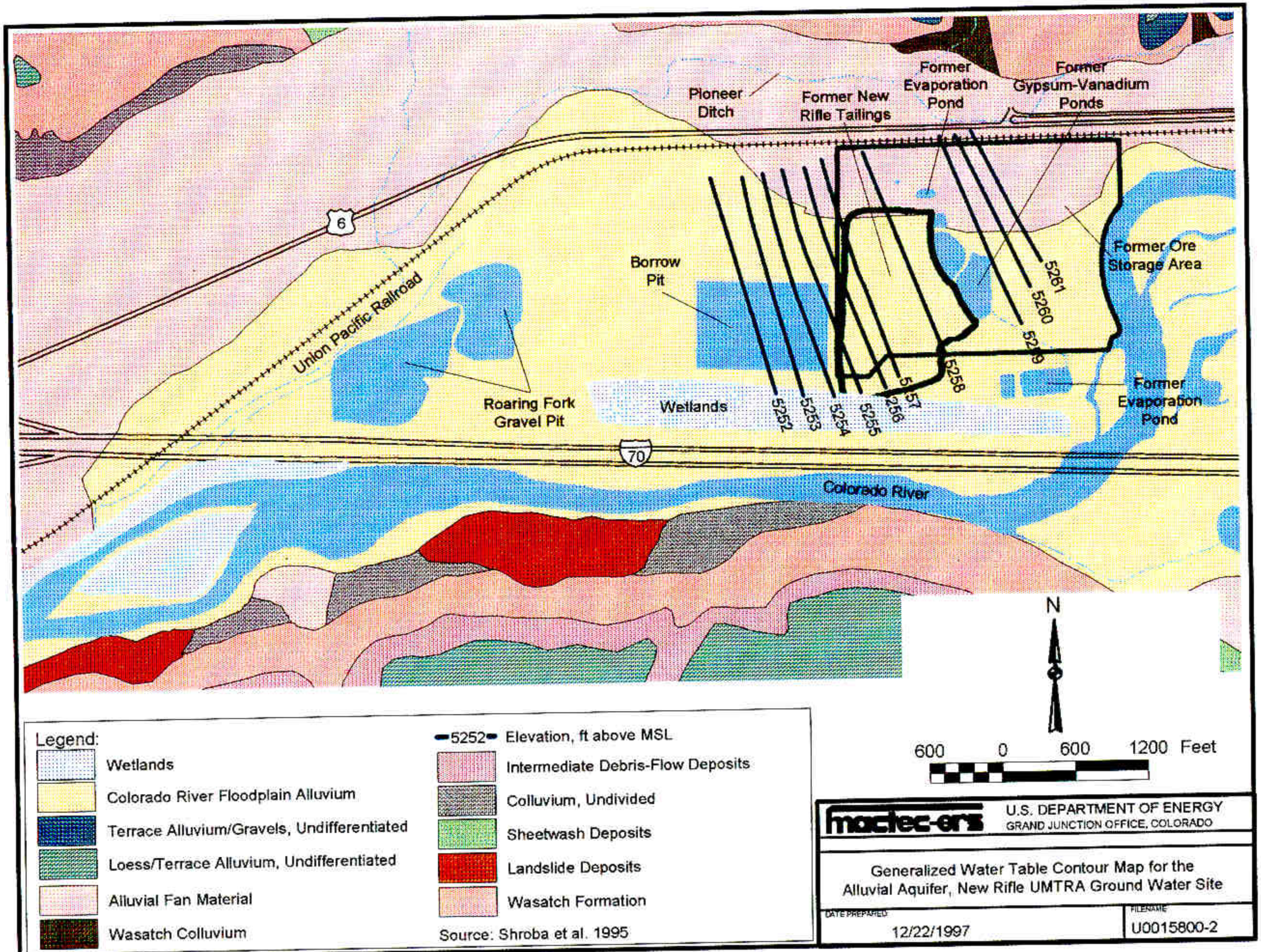


Figure 3–2. Generalized Water Table Contour Map for the Alluvial Aquifer, New Rifle UMTRA Ground Water Site

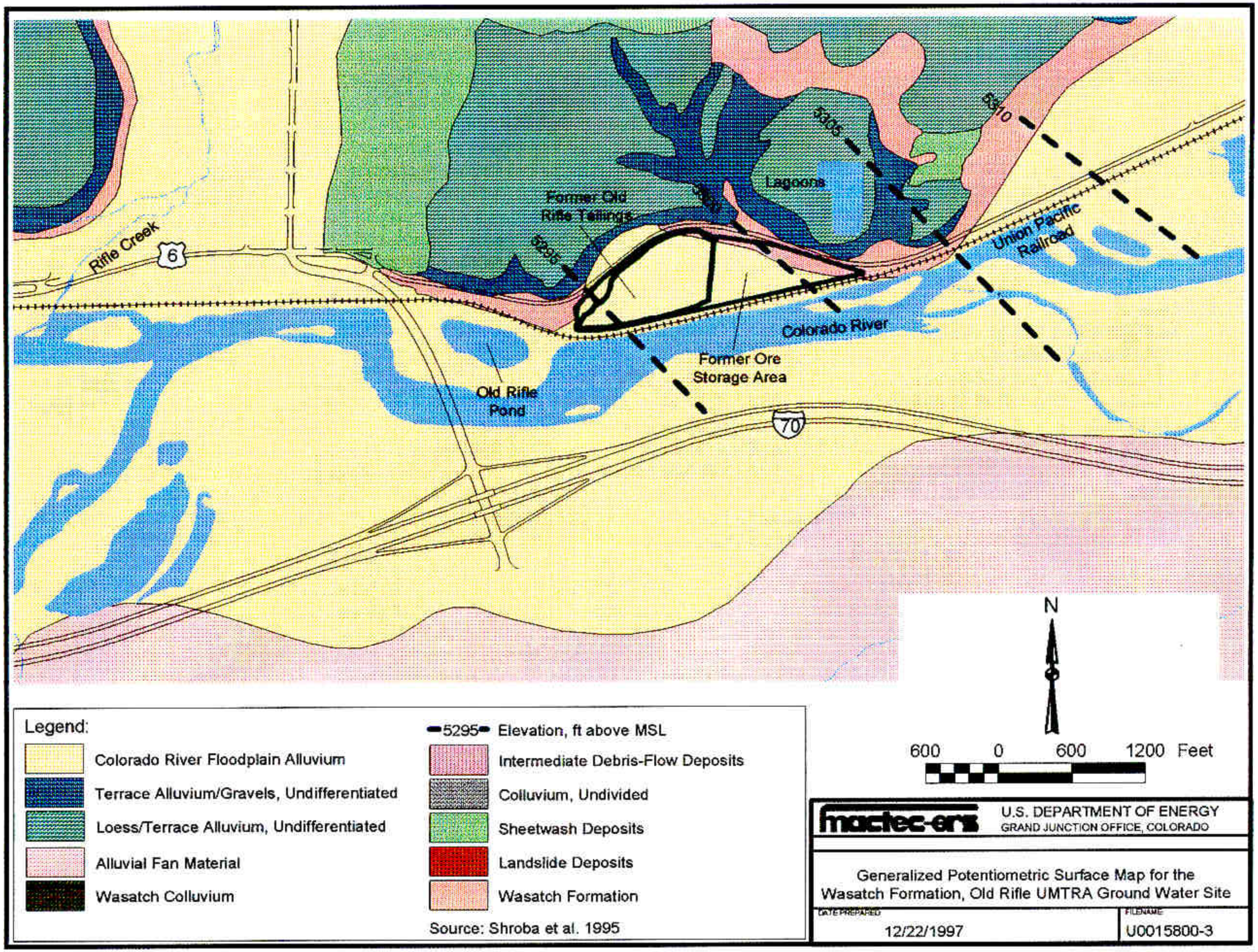


Figure 3–3. Generalized Potentiometric Surface Map for the Wasatch Formation, Old Rifle UMTRA Ground Water Site

3.3.2 New Rifle Site

As at the Old Rifle site, the Wasatch Formation at the New Rifle site is composed of interbedded siltstone, shale, and sandstone; the siltstone and shale units form aquitards and the underlying sandstone units form an aquifer or series of aquifers with semiconfined to confined characteristics. The uppermost 3 to 5 ft of the Wasatch Formation is considered to be a weathered bedrock section that is hydraulically well connected to the overlying saturated alluvial/colluvial deposits. Some lithologic logs for previously installed wells show sandstone or a combination of sandstone with shale or siltstone as the first unit encountered when drilling through the Wasatch. However, the majority of data suggest that the Wasatch is a stratified hydrogeologic unit consisting of 3 to 5 ft of weathered shale, siltstone, and occasionally sandstone underlain by up to 80 ft of competent siltstone and shale that forms an aquitard. Underlying this aquitard is a saturated, semiconfined to confined sandstone aquifer of undetermined thickness. The lithologic logs supporting this conceptual model were prepared while logging cuttings discharged during mud and air rotary drilling, and as such are of limited integrity.

Depth to the top of the Wasatch Formation at the New Rifle site typically ranges from 25 to 45 ft; the contact surface dips to the south and southwest. A modest-relief subcrop ridge extending southwest beneath the site is also suggested by the lithologic logs and may influence ground-water flow in the alluvial aquifer by reducing saturated thickness and, consequently, transmissivity. The depth to water for Wasatch Formation wells at the New Rifle site is typically in the range of 7 to 15 ft, although some depths exceed 75 ft. Some well-pairs in which both wells are completed at different elevations within the Wasatch Formation show vertically upward gradients, some show the reverse, and others show no vertical gradient. A comparison of Wasatch Formation hydraulic heads with alluvial aquifer heads suggests that gradients between the two saturated units tend to be directed upward, but this relationship is not entirely consistent. The most plausible explanation for the distribution of vertical gradients is that some of the Wasatch wells are completed in aquitard sections, thereby giving unrepresentative head measurements. Outside of this condition, the hydraulic gradients are expected to be consistently directed upwards. An attempt will be made during the field investigation to improve the understanding of this situation.

Recharge to the Wasatch Formation at the New Rifle site occurs mainly as precipitation falling directly on the outcrop to the north in the vicinity of the Grand Hogback. Discharge reportedly occurs mainly as upward leakage through the alluvial aquifer to the Colorado River (DOE 1996e), although this interpretation is not based on site-specific data. Limited additional discharge also occurs as seepage from springs on the steep outcrop above Highway 6, as lateral flow into the alluvium along the steep subcrop in this same area, and as vertical leakage into the alluvial aquifer due to the irregularly distributed vertical hydraulic gradients described above.

Hydraulic conductivity estimates from slug tests conducted on Wasatch Formation wells at the New Rifle site indicated that hydraulic conductivity ranges from 0.012 to 0.41 ft/day (DOE 1996e). The three lowest estimates were obtained from wells screened between 60 and 90 ft below ground surface, and the higher estimates were obtained from wells screened in shallower sections. These data alone, however, do not allow characterization of the distribution of hydraulic conductivity among the various units of the Wasatch. Additional data will be collected during the field investigation to further this objective. Coupling the hydraulic conductivity estimates with the southwest-oriented hydraulic gradients of 0.003 ft/ft (Figure 3–4) and an assumed porosity of 0.15 yields estimated average linear velocities ranging from 0.1 to 3 ft/day.

3.4 Summary of Hydrologic Data Needs

Hydrologic data needs are summarized below. Additional hydrologic data will be collected to evaluate the suitability of the natural flushing and the supplemental standards alternatives.

3.4.1 Surface Water

The recharge/discharge relationship between the Colorado River and the alluvial/colluvial aquifer has not been quantified. To quantify this relationship, upstream and downstream stage-discharge data for the river will be obtained from the U.S. Geological Survey (USGS). River-gauging stations will be installed at or upstream of the Old Rifle site and at or downstream of the New Rifle site. The combined USGS and site-specific data sets will be used to estimate rates of seasonal gain and loss for the river reaches that border the two sites and adjacent areas of interest. Seasonal gains and losses will be compared with estimates of the same obtained from ground-water data collected during the field investigation.

3.4.2 Ground Water

Data defining the water table topography, piezometric head distribution, alluvium/Wasatch contact topography, saturated thickness, lithology, location and thickness of the Wasatch aquitard, distribution of weathered Wasatch bedrock, horizontal and vertical hydraulic conductivity, vertical gradients between the alluvial aquifer and the Wasatch are limited. Additional on-site and off-site monitoring wells will be installed in both the alluvial/colluvial aquifer and the Wasatch Formation to fill these data gaps. Water-level measurements will be made in all on-site and off-site monitoring wells and in any accessible private, industrial, and municipal wells. Aquifer tests will be conducted in selected new and existing on-site and off-site monitoring wells. Aquifer tests will include slug withdrawal tests and pumping tests. At least one pumping test will be conducted in each aquifer at each of the two sites. Pumping-test wells will also be slug tested to allow extrapolation to pumping-test-equivalent hydraulic conductivity estimates for the wells exposed only to slug testing.

Water-level measurements at all new and existing monitoring wells and at all accessible private wells will be made quarterly throughout the study. Continuous water-level logging will also be performed on at least two alluvial/Wasatch well pairs at each site.

During the installation of all new monitoring wells, 2-ft split-barrel samples will be collected every 5 ft during borehole advancement to characterize lithology and to identify the alluvium-colluvium contact, alluvium- or colluvium-Wasatch contact, nature of the weathered Wasatch zone, and the nature of the Wasatch aquitard.

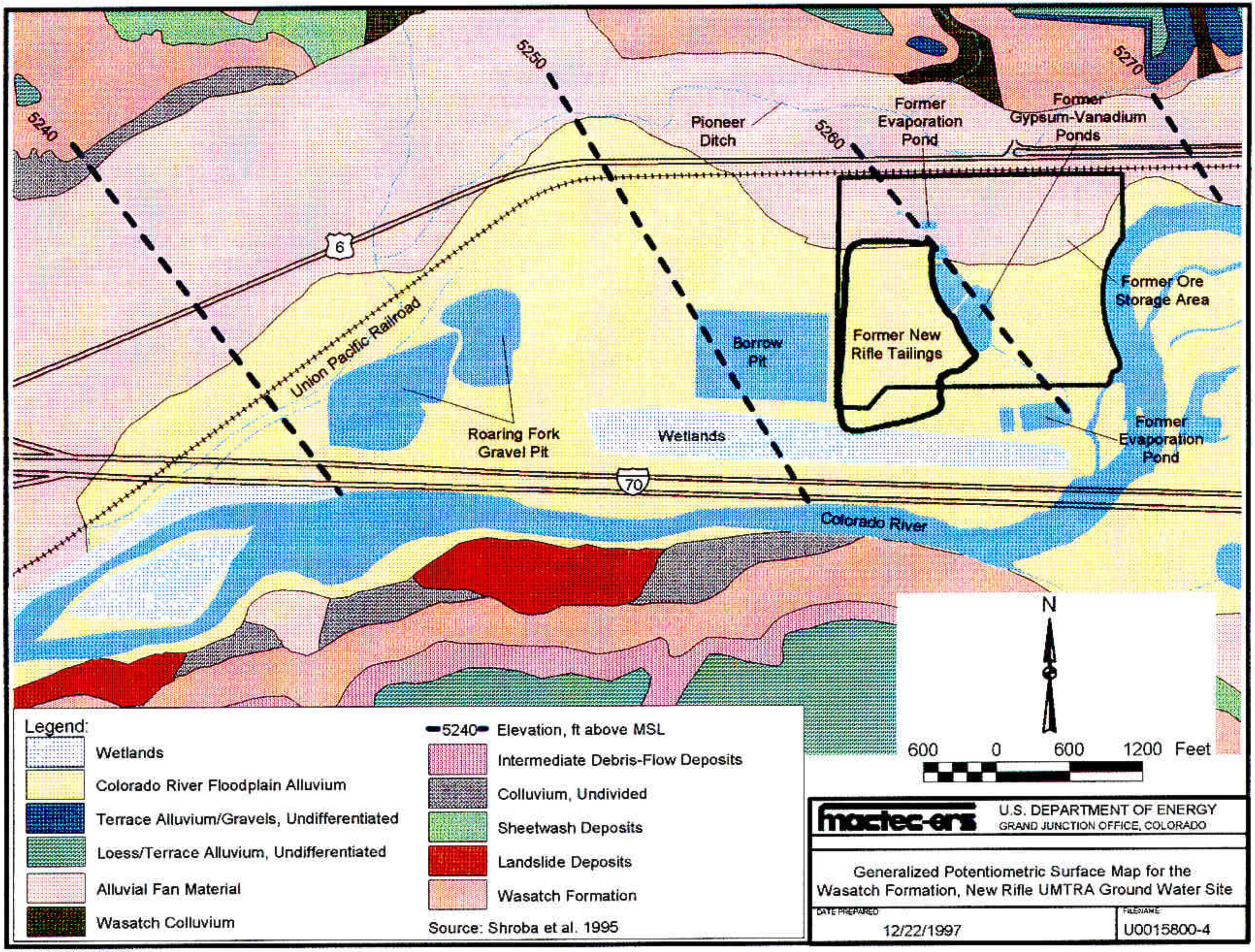


Figure 3–4. Generalized Potentiometric Surface Map for the Wasatch Formation, New Rifle UMTRA Ground Water Site

4.0 Geochemistry

DOE collected ground-water quality data from the Old and New Rifle processing sites and vicinity from 1981 through 1994. These data are accessible in the SEE_UMTRA database and were used previously as the basis to prepare the baseline risk assessment (BLRA) (DOE 1996b) and the SOWP (DOE 1996e).

Ground-water sampling to monitor water quality continued in 1996 and 1997. However, many of the monitor wells installed near the former source areas that were used to develop the BLRA and SOWP could not be resampled because they were removed during the surface remediation in 1995. Consequently, changes in water quality beneath the former tailings piles after the source materials were removed could not be completely evaluated.

Current site conditions were evaluated using the most recent sampling information to assess ground-water and surface-water quality for the purpose of identifying data gaps and additional field characterization needed to evaluate the applicability of the remediation strategy presented in Section 1.2.3.

4.1 Source Areas and Contaminants

Ground-water contamination was probably a result of mill-process water draining from the tailing piles, seepage from evaporation ponds and, to a lesser extent, seepage from stockpiled ores. The primary constituents released from the stockpiles of ore would have been relatively soluble components such as uranium, vanadium, selenium, arsenic, and molybdenum. Uranium is the most likely contaminant to have been released from the ores. Nitrate would not be a significant constituent of the ores and would only enter the ground water during the milling process.

Process chemicals provided a source for sulfate, nitrate, and ammonium contamination. Both the Old and New Rifle sites used sulfuric acid (H_2SO_4) to leach uranium and vanadium. The sulfuric acid leaching solutions were neutralized with ammonia (NH_3). The spent neutralization solutions were probably discharged to the evaporation ponds. The primary areas of infiltration of the contaminated process water would have occurred at the former evaporation ponds and former tailings pile areas shown on Figures 1–2 and 1–3.

Merritt (1971) indicates that salt roasting and acid leaching of roscoelite-type uranium-vanadium ores also contributed sodium chloride (NaCl) to the tailings pile and thus to the ground water at both the Old and New Rifle sites. Vanadium oxidation and neutralization also added sodium chlorate ($NaClO_3$), sodium hydroxide (NaOH), and sodium carbonate (Na_2CO_3). At the Old Rifle site, ammonia gas was used as a neutralizer, and ferric sulfate ($Fe_2(SO_4)_3$) was used to precipitate ferric vanadate. At the New Rifle site, a solvent extraction process used ethylhexylphosphoric acid with kerosene as a carrier. Also at the New Rifle site, ammonium chloride (NH_4Cl) was used in a purifying step.

4.1.1 Quantity Estimates of Process Water and Chemicals

The amount of process water and chemicals (sulfuric acid, ammonia, and nitrate) used at the New and Old Rifle sites is estimated on the basis of a typical usage of 500 to 1,000 gallons of water per ton of ore (Merritt 1971). If tailings volumes are used to estimate the amount of ore processed, an estimated 190 to 370 million gallons of water were used in 16 years of operation at the Old Rifle millsite and 1,400 to 2,800 million gallons of water were used in 15 years of operation at the New Rifle millsite (DOE 1996e). Process water was discharged to evaporation ponds at both sites.

Chemical usage per ton of ore processed is estimated at 30 to 50 pounds of sulfuric acid, 1 to 30 pounds of ammonia, and 15 to 20 pounds of ammonium nitrate (HEW 1962). Due to the lack of specific information on the mill, more precise estimates for chemical and water quantities are unavailable.

4.2 Source Area Contamination

Limited information is available on the chemical composition of the contaminated process water and pore fluids that could have infiltrated to the ground water from the evaporation ponds and tailings piles. However, an estimate of contaminant concentrations in the tailings pore fluids can be obtained from leach studies of the tailings material. Water leaching tests from tailings core samples obtained from both the Old and New Rifle sites were preformed by Markos and Bush (1983). Average concentrations for selected contaminants (mass of analyte extracted per mass of tailings) are presented in Table 4–1. Also included in Table 4–1 are results of water leachate of soil core samples collected at selected background locations between the Colorado River and east of the former New Rifle millsite. Surface samples collected at these background locations were eliminated from the average to minimize any bias that may be introduced from windblown tailings.

Table 4–1. Average Concentration of Selected Contaminants in Leachate from Tailings and Background Soils

Constituent	New Rifle Tailings Leachate (µg/g)	Old Rifle Tailings Leachate (µg/g)	Background Leachate (µg/g)
Arsenic	1.7	5.4	0.5
Chloride	81.2	144.4	76.0
Manganese	4.1	2.8	0.4
Molybdenum	1.4	3.3	0.5
Selenium	3.6	2.3	0.4
Sulfate	11,226	2,123	303
Uranium	0.3	3.2	0.3
Vanadium	19.6	106.5	44.4
Number of samples	37	71	7

Average concentrations of all the selected constituents in tailings core samples collected at the Old Rifle site are elevated with respect to the average background values. These elevated constituents in the leachate represent water-soluble contaminants that could have entered the ground water as process water, precipitation, or irrigation runoff leached through the tailings piles.

Similarly, at the New Rifle site all the tailings leachate samples, with the exception of uranium and vanadium, are elevated with respect to natural background concentrations. The relatively low uranium and vanadium leachate concentrations in the tailings material reflect the more efficient extraction process used at the New Rifle site and suggest that a significant amount of the uranium and vanadium detected in the ground water may be from process fluids discharged to the evaporation ponds and from precipitation leaching through stockpiles of ore, rather than from the tailings material.

The tailings piles, evaporation ponds, and other contaminated surface materials were completely removed from both sites by 1995 as part of the UMTRA Surface Project. Therefore, the potential for infiltration of tailings-related contaminants remained until that time. However, the soils that were exposed after removal of the tailings piles, evaporation ponds, and stockpile areas have not been evaluated to determine if a residual source of contaminants is available that could leach into the ground water.

4.3 Alluvial Aquifer Contamination

The alluvial aquifer is the aquifer that is most affected by contamination. A BLRA (DOE 1996b) was prepared to identify potential adverse human-health risks associated with exposure to ground-water contamination beneath the Rifle sites. Results of the BLRA indicate that no human-health risks are associated with current land use at the Rifle sites because ground water beneath the sites is not currently used for drinking. However, since the ground-water use could change, the BLRA considered possible future use. Future risk was evaluated by assuming a residential well constructed in the most contaminated area of the ground-water plume was the only source of drinking water. Therefore, the estimated health risks are considered conservative. Contaminants detected in the ground water that could cause adverse health effects if taken into the body are called contaminants of potential concern (COPCs). To select COPCs for the New and Old Rifle sites, the chemical constituents were first screened to see if concentrations exceeded background. If the maximum detected concentration of a constituent was within the acceptable nutritional requirement levels, it was not retained as a COPC. If the maximum detected concentration was in the high end of dietary ranges but was of low toxicity, it was not retained. As a result, 20 constituents at the New Rifle site and 13 constituents at the Old Rifle site were considered COPCs (DOE 1996b). Table 4–2 summarizes the COPCs and the maximum concentrations detected in alluvial ground-water samples from the most recent sampling (November 1996 and April 1997). Table 4–2 also presents the UMTRA maximum concentration limits (MCLs) for ground-water protection, the EPA health-based drinking water advisory values for short-term exposure of a 10-kilogram (kg) child, and the range in natural background concentrations for each constituent.

Table 4–2. Maximum Concentrations of Contaminants of Potential Concern Detected in the Alluvial Aquifer in 1996 and 1997

COPCs	Maximum Concentration (mg/L)		UMTRA MCL (mg/L)	Health Advisory (mg/L)	Range in Natural Background (mg/L)[b]
	New Rifle	Old Rifle[a]			
Ammonium	745				<0.1 – 1.5
Antimony	0.0016			0.01	<0.003
Arsenic	0.232	0.0085	0.05		0.001 – <0.01
Cadmium	0.022		0.01	0.04	<0.001
Chloride	664				62 – 261
Fluoride	6.7	1.2			0.40 – 1.2
Iron	17.7	7.73			<0.03 – 2.4
Lead	0.0047		0.05		<0.001 – <0.01
Manganese	8.82	2.92			0.10 – 4.2
Molybdenum	7.3	0.0349	0.1	0.04	<0.01 – 0.06
Nitrate	1,080		44.0	44.0	<0.1 – 7.8
Selenium	0.663	0.0955	0.01		<0.002 – 0.013
Sodium	2,220				177 – 617
Sulfate	6,620	924			443 – 977
Uranium	0.362	0.0869	0.044		0.017 – 0.046
Vanadium	24.7	ND[c](0.006)		0.08	<0.01 – 0.05
Lead-210[d]	ND[c](1.36)	0.89			1.4 – 2.3
Polonium-210[d]	ND[c](0.25)	0.27			0.0 – 0.8
Radium-226[d]	0.37	0.75	5		0.0 – 2.5
Thorium-230[d]	ND[c](0.64)	ND[c](0.64)			0.0 – 0.4

[a]Blank spaces indicate that the constituent is not a COPC at the Old Rifle site.
[b]Minimum and maximum values from background wells RFO–597, –598, –605, and –606 used in the BLRA (DOE 1996b)
[c]ND = not detected at reported value
[d]picocuries per liter (pCi/L)

Results from the most recent sampling (Table 4–2) indicate that the more contaminated alluvial ground water is at the New Rifle site where arsenic, cadmium, molybdenum, nitrate, selenium, uranium, and vanadium exceed the UMTRA MCL or the health advisory. In addition, the maximum ground-water concentrations of ammonium, chloride, fluoride, iron, manganese, sodium, and sulfate are several times greater than the upper limit of natural background concentrations. Antimony, lead, and the uranium decay products lead-210, polonium-210, radium-226, and thorium-230 were either not detected or did not exceed the natural background levels.

Contaminant concentrations from the most recent sampling at the Old Rifle site indicate that selenium and uranium are the only COPCs in the alluvial ground water that exceed the UMTRA MCL or the health advisory level (Table 4–2). Concentrations of iron and polonium-210 (a uranium decay product) exceed the upper limits of natural background. Concentrations of the remaining COPCs listed in Table 4–2 are within the ranges of natural background or are less than detection limits. However, higher contaminant concentrations may be present at the Old Rifle site; water quality cannot be evaluated beneath the former tailings because no monitor wells remain within the area of the former piles.

4.3.1 Extent of Alluvial Ground-Water Contamination

An evaluation of the current extent of contamination is presented below for each COPC listed in Table 4–2. Contaminant plume maps based on the most recent water sampling conducted in 1996 and 1997 are provided for selected indicator constituents. Included on the maps are the most recent historical results to provide supplemental information where current monitor well coverage does not exist. Although the historical data may not indicate current site conditions, the data are useful in evaluating changes in constituent concentrations over time.

Ammonium

Results of ammonium analyses on ground water collected from the most recent sampling at the New Rifle site are shown on Figure 4–1. The highest ammonium concentrations are in ground water from monitor wells RFN–590, –635, and –636 located 1,000 to 2,000 ft downgradient from the former tailings area. The maximum concentration of 745 milligrams per liter (mg/L) was detected at monitor well RFN–635, which is approximately 1,500 ft southwest of the former tailings pile. The current extent of contamination, delineated by the 50 mg/L ammonium boundary, suggests that the leading edge of the ammonium plume is approximately 1 mi downgradient from the former tailings area near monitor well RFN–603.

Historically, ammonium concentrations have been much lower at the Old Rifle site. Recent sampling results indicate that ammonium concentrations are near background levels. Because some ammonium oxidizes to nitrate in oxygen-rich alluvial ground water, oxidation, dilution, and dispersion will be the primary controls on ammonium concentrations.

Antimony

Antimony was detected in concentrations of 0.0016 mg/L at the New Rifle site and less than 0.001 mg/L near the Old Rifle site in water samples collected during the most recent ground-water sampling. These concentrations are within the range of natural background. Antimony was historically detected at a maximum concentration of 0.174 mg/L at the New Rifle site and at a maximum concentration of 0.007 mg/L near the Old Rifle site, but generally antimony concentrations have been relatively low (less than 0.03 mg/L) at both sites. The relatively high historical concentrations were detected in ground water obtained directly under the former tailings pile at each site or immediately downgradient. All the known antimony compounds are very soluble; therefore, precipitation is not expected to control concentrations at the sites.

Although very little is known about adsorption/desorption behavior of antimony species (Rai and Zachara 1984), adsorption appears to have attenuated concentrations of this ion at both sites.

Arsenic

The historical maximum arsenic concentration of 2.4 mg/L was detected at the New Rifle site in a water sample collected from on-site well RFN–594, located near the former vanadium/gypsum ponds. This well could not be sampled during the most recent round because it was removed during the surface remediation. However, monitor well RFN–658 is located in the same general area, approximately 150 ft northwest of former monitor well RFN–594. The maximum arsenic concentration of 0.232 mg/L was detected at well RFN–658 during the most recent sampling at the New Rifle site, which suggests that arsenic concentration is being attenuated, probably by adsorption and transport. Concentrations are at or near the detection limit in downgradient wells probably because of adsorption onto the aquifer matrix.

The maximum arsenic concentration detected near the Old Rifle site during the most recent sampling is within the range of natural background. Historically, the maximum concentrations at the Old Rifle site have been much lower than those at the New Rifle site and are apparent only in the alluvial ground water directly under the site of the former tailings pile. On-site wells at the Old Rifle site could not be sampled during the most recent round because all the on-site wells were removed during the surface remediation. However, the historical data for the Rifle sites demonstrate that arsenic concentrations have been greatly attenuated by adsorption; further attenuation is expected through transport and time.

Cadmium

Relatively high concentrations have historically been detected close to the former New Rifle tailings pile; up to 0.13 mg/L were detected in ground-water samples from former monitor well RFN–619, which was located a few hundred feet west of the southwest corner of the tailings pile before being removed during surface remediation. Because well RFN–619 could not be resampled, the degree of cadmium attenuation must be inferred by examining the analytical results from monitor well RFN–659, which is approximately 250 ft northeast of former monitor well RFN–619. The maximum cadmium concentration of 0.022 mg/L from the most recent sampling at the New Rifle site was detected in water from monitor well RFN–659. This value is consistent with historical concentrations detected in downgradient wells.

Cadmium was not detected at the Old Rifle site in ground water collected during the latest sampling. Equilibrium with the mineral otavite ($CdCO_3$) may limit solution concentrations of cadmium species (Rai and Zachara 1984). Modeling with PHREEQE (Parkhurst et al. 1980) indicates that ground water at the Rifle sites is in equilibrium with otavite (DOE 1996e). Thus, most cadmium in the ground water has precipitated in the subsurface near the source of contamination.

Chloride

Historically, chloride concentrations in the most contaminated ground water at the New Rifle site have been about 4 times background. The most recent sampling results indicate that the highest

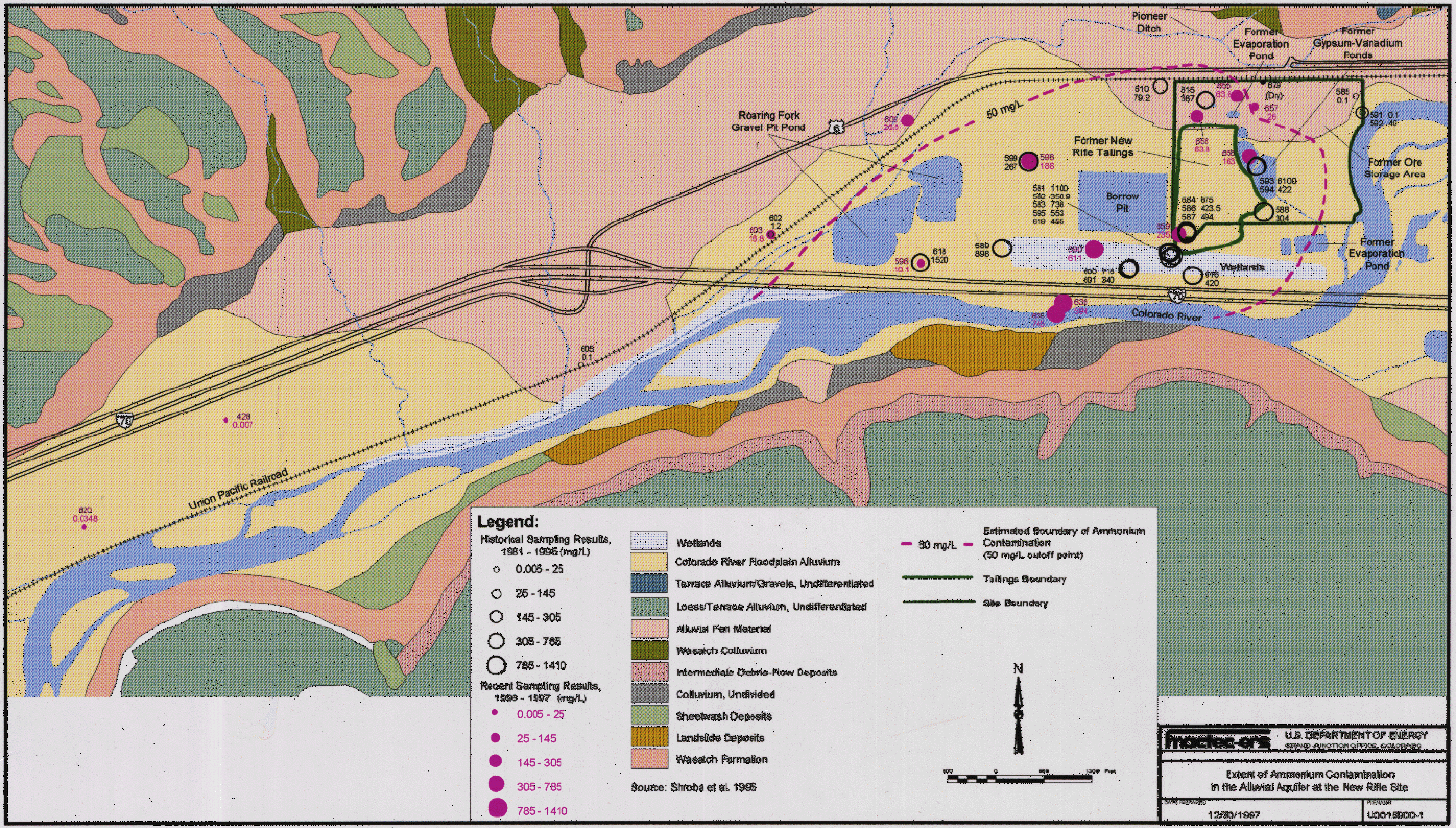


Figure 4–1. Extent of Ammonium Contamination in the Alluvial Aquifer at the New Rifle Site

concentration in the plume area is 322 mg/L at monitor well RFN–590. All other chloride values near the former tailings area have decreased to the range of natural background.

Maximum chloride concentrations at the New Rifle site were detected in the two wells farthest downgradient: 664 mg/L at well RFN–620 and 431 mg/L at well RFN–428. The maximum chloride concentration detected at the Old Rifle site is 233 mg/L in ground water collected from upgradient background well RFO–605. Chloride is a nonreactive ion and is mobile in ground water. Therefore, decreases in chloride concentrations will be due to dilution and dispersion rather than adsorption.

Fluoride

Maximum fluoride concentrations of 6.7 mg/L (RFN–636) and 1.2 mg/L (RFO–605) were detected during the most recent sampling at the New Rifle site and at the Old Rifle site, respectively. The 1.2 mg/L value detected at the Old Rifle site is within the range of natural background. Near the location of the former tailings pile at the New Rifle site, fluoride concentrations in most wells have historically varied from 2 to 9 mg/L. Farther from the pile, concentrations in individual wells are lower (from <1 to 5 mg/L), and concentration-versus-time plots show stability over time. This stability suggests that fluoride is in equilibrium with solubility-controlling solids. Modeling with PHREEQE (Parkhurst et al. 1980) indicates that fluoride concentrations in downgradient wells at both sites are in equilibrium with the mineral fluorite (CaF_2) (DOE 1996e). Thus, fluoride is precipitating as fluorite as it moves downgradient. These deposits will form a secondary source of fluoride that will continue to release fluoride in equilibrium amounts (from <1 to about 5 mg/L) until the solids are completely dissolved.

Iron

The maximum iron concentrations detected during the most recent sampling round were 17.7 mg/L (RFN–655) at the New Rifle site and 7.7 mg/L (RFO–600) at the Old Rifle site. Historically, iron concentrations up to 97 mg/L at the New Rifle site have been observed to decrease to less than 0.1 mg/L within 500 ft downgradient of the former tailings pile. Iron is soluble under acidic or reducing conditions but forms insoluble hydrated oxides under oxidizing conditions at pH values greater than 6. Ground water in all downgradient wells is oversaturated with respect to these iron oxides; with time, oxygen is expected to diffuse into the ground water and iron concentrations will decrease to background levels (<0.03 to 2.4 mg/L), due to both precipitation and dilution.

Lead

The maximum lead concentrations detected during the most recent sampling were 0.0047 mg/L (RFN–598) at the New Rifle site and 0.0096 mg/L (RFO–598) at the Old Rifle site. Lead concentrations are generally within the range of natural background or below the detection limit at both Rifle sites. However, concentrations as high as 0.08 mg/L (RFN–584) were historically detected in ground water directly beneath the tailings pile at the New Rifle site. Adsorption has been effective in removing lead from ground water, and further decreases in lead concentrations are expected in the future.

Manganese

Manganese is present at the New Rifle site at a maximum concentration of 8.8 mg/L (RFN–636). At the Old Rifle site, manganese concentrations are within the range of natural background. Historically, ground-water samples at the New Rifle site are at or near saturation with respect to the mineral rhodochrosite ($MnCO_3$), and in the past, manganese probably precipitated as rhodochrosite (DOE 1996e). These deposits will form a secondary source of manganese that will continue to release manganese in equilibrium amounts (about 1 to 10 mg/L) until the solids are completely dissolved. As a result, decreases in concentration will be due to dilution and dispersion rather than adsorption.

Molybdenum

Molybdenum is present at the New Rifle site at a maximum concentration of 7.34 mg/L (RFN–659). At the Old Rifle site, molybdenum concentrations are within the range of natural background (<0.01 to 0.06 mg/L). Molybdenum occurs in the contaminated ground water as molybdate (MoO_4^{2-}), a negatively charged ligand (DOE 1996e). As with most negatively charged ligands, molybdenum adsorption is most effective under acidic conditions (pH of approximately 3 to 4). Thus, molybdenum adsorption in the near-neutral pH ground water at the Rifle sites will be less important than dilution as a mechanism for decreasing concentrations.

Nitrate

Nitrate concentrations presented in Figure 4–2 are higher near the former location of the New Rifle tailings pile and decrease as ground water moves farther downgradient. The maximum nitrate concentration of 1,080 mg/L was detected during the most recent sampling at monitor well RFN–659 located near the southwest corner of the former tailings pile. Historically, nitrate concentrations have been much lower at the Old Rifle site. Recent sampling results indicate that nitrate concentrations are near background levels at the Old Rifle site.

A nitrate dispersion pattern similar to that of ammonium is delineated by the 44 mg/L nitrate MCL boundary shown in Figure 4–2. However, the relatively high mobility of nitrate in ground water and the elevated levels detected farther downgradient in private well 428 suggest that the nitrate plume could extend farther downgradient than the ammonium plume. Additional ground-water investigations downgradient from monitor well 603 are required to better define the leading edge of the nitrate plume. Because nitrate is highly mobile under almost all conditions, dilution and dispersion will be the primary controls on concentrations of this species.

Selenium

Selenium has historically occurred at both Rifle sites at maximum concentrations ranging from 0.4 to 0.8 mg/L. The maximum selenium concentrations detected during the most recent sampling were 0.663 mg/L (RFN–658) at the New Rifle site and 0.096 mg/L (RFO–590) at the Old Rifle site. Figure 4–3 shows selenium concentrations at the New Rifle site and a preliminary estimate of the extent of selenium contamination. The dominant selenium species in ground water at both sites is hydrogen selenite ($HSeO_3^{1-}$), followed by selenite (SeO_3^{2-}). Adsorption of these selenium anions is most effective under acidic conditions (pH less than 4). Thus, both anionic species are mobile in

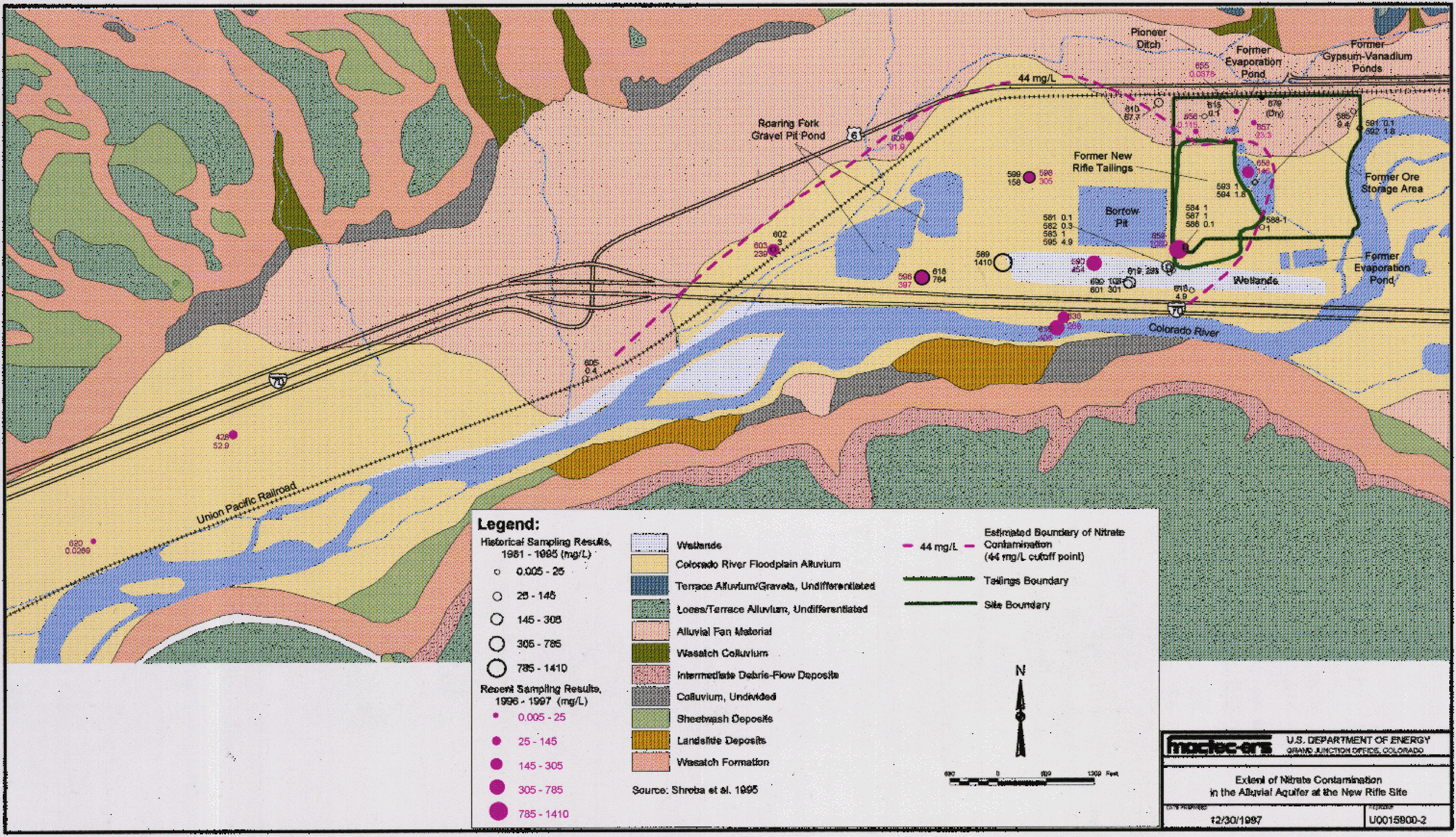


Figure 4–2. Extent of Nitrate Contamination in the Alluvial Aquifer at the New Rifle Site

Figure 4-3 will be provided upon request. Click Wendee Ryan or Michelle Smith to request.

Figure 4–3. Extent of Selenium Contamination in the Alluvial Aquifer at the New Rifle Site the near-neutral ground water at the site and concentrations are increasing in some areas as pH increases. Therefore, dilution and dispersion are likely to be the primary mechanisms that decrease selenium concentrations at the site.

Sodium

Sodium has historically occurred as a contaminant at both sites, at concentrations up to 16,400 mg/L (RFN–584) at the New Rifle site and 1,310 mg/L (RFO–584) at the Old Rifle site. The maximum sodium concentrations detected during the most recent sampling are 2,220 mg/L (RFN–635) at the New Rifle site and 577 mg/L (RFO–605) at the Old Rifle site. Sodium forms very soluble bicarbonate, chloride, and sulfate salts; thus, those salts will not precipitate. A primary mechanism for sodium removal is cation exchange for calcium within clay minerals. However, the alluvium at the Rifle sites appears to have little cation exchange capacity. Therefore, dilution and dispersion will be the more effective means of decreasing sodium concentrations at the sites.

Sulfate

Sulfate concentrations are elevated above background at both Rifle sites and occurred historically at concentrations up to 40,400 mg/L (RFN–593) at the New Rifle site and up to 2,640 mg/L (RFO–584) at the Old Rifle site. The maximum sulfate concentrations detected during the most recent sampling are 6,620 mg/L (RFN–635) at the New Rifle site and 924 mg/L (RFO–597) at the Old Rifle site. The sulfate ion (SO_4^{2-}) is the dominant sulfur species in ground water at the site, followed by calcium sulfate ($CaSO_4$). Modeling with the computer code PHREEQE (Parkhurst et al. 1980) indicates that gypsum is at equilibrium and should precipitate (DOE 1996e). These precipitates would then become a secondary source of contamination and would supply sulfate to the ground water in equilibrium concentrations (1,000 to 2,000 mg/L) until solids are completely dissolved.

Uranium

The maximum uranium concentrations detected during the most recent sampling were 0.362 mg/L (RFN–655) at the New Rifle site and 0.087 mg/L (RFO–590) at the Old Rifle site. Historically, uranium was detected in concentrations up to 1.31 mg/L (RFN–593) at the New Rifle site and up to 2.1 mg/L (RFO–583) at the Old Rifle site. The current extent of the uranium plume at the New Rifle site, shown in Figure 4–4 as the 0.044 mg/L MCL boundary, is consistent with the general extent of contamination observed for the ammonium and nitrate plumes shown in Figures 4–1 and 4–2, respectively. Uranium, like nitrate, was detected at elevated levels in the downgradient private well 428, which suggests that the uranium plume could be more extensive. Additional ground-water investigations downgradient from monitor well 603 are required to better define the leading edge of the uranium plume.

Uranium occurs in ground water at the New Rifle site predominantly as a uranyl carbonate complex (e.g., $UO_2(CO_3)_3^{4-}$). This complex is mobile in neutral to alkaline ground water. Modeled uranium species in monitor well RFO–584 at the Old Rifle site (formerly located on the site just upgradient of the tailings pile before being removed during the surface remediation) resemble those in ground water at the New Rifle site (DOE 1996e). Uranium is present at the Old Rifle site in ground water in monitor well RFO–583 (formerly located beneath the tailings pile before being removed during the surface remediation) primarily as uranyl biphosphate ($UO_2HPO_4^{2-}$). This complex is also likely to be mobile; therefore, during oxidizing conditions dilution will be the primary control on uranium concentrations as ground water enters the Colorado River.

Vanadium

Historically, elevated vanadium concentrations were detected at both sites, but the highest concentrations were detected at the New Rifle site. The maximum vanadium concentration detected during the most recent sampling was 24.7 mg/L at the New Rifle site in monitor well RFN–658 located near the former vanadium/gypsum pond. Concentrations appear to decrease to background levels within a few thousand feet downgradient of the former New Rifle tailings pile. Vanadium was not detected (less than 0.006 mg/L) at the Old Rifle site. Figure 4–5 shows the current extent of vanadium contamination greater than 1.0 mg/L at the New Rifle site and historical vanadium concentrations in the alluvial ground water.

Because of the oxidizing conditions at the sites, vanadium exists in ground waters in its maximum oxidation state (5+) as a vanadate ion (primarily $HV_2O_7^{3-}$). Modeling with PHREEQE does not indicate the presence of solubility-controlling solids, and thereby argues against the possibility of attenuation by precipitation (DOE 1996e). Little is known about the adsorptive behavior of vanadium species, but vanadates are known to be adsorbed by iron oxides (Rai and Zachara 1984). Overall, vanadium does not appear to be mobile at the Rifle sites; therefore, adsorption will be the primary mechanism for decreasing concentrations in ground water.

4.4 Plume Migration

At least two separate plumes have been mobilized from the New Rifle site. Evidence of an early plume migration, probably associated with the early operations at the millsite, can be inferred by examining changes in concentrations of indicator contaminants over time for individual monitor wells. That is, indicator concentrations in ground-water samples tend to decrease in monitor wells located adjacent to the downgradient edge of the former tailings pile, and concentrations tend to increase in ground water from monitor wells located near the leading edge of the plume. For example, the plot of uranium concentration versus time shown in Figure 4–6 indicates that uranium concentrations have been decreasing for the last 10-year sampling period in off-site monitor well RFN–590, which is located adjacent to the downgradient edge of the former tailings pile. Conversely, uranium concentrations have been increasing for the last 10-year period for off-site monitor well RFN–603, which is located near the downgradient edge of the plume. The general distribution of off-site monitor wells that tend to have either decreasing or increasing uranium concentrations in ground water is shown in Figure 4–7. The direction in which the contaminant concentrations are increasing reflects the direction of the plume migration and is consistent with the ground-water flow to the southwest. Other indicator constituents such as ammonium and nitrate show a similar relative relationship to upgradient and downgradient concentrations.

A more recent plume migration can be inferred by examining concentration-versus-time plots for several wells located on the New Rifle millsite and tailings area. For example, uranium concentrations in ground water collected from upgradient on-site well RFN–655 appear to be decreasing, as shown in Figure 4–8; concentrations in water collected from downgradient on-site

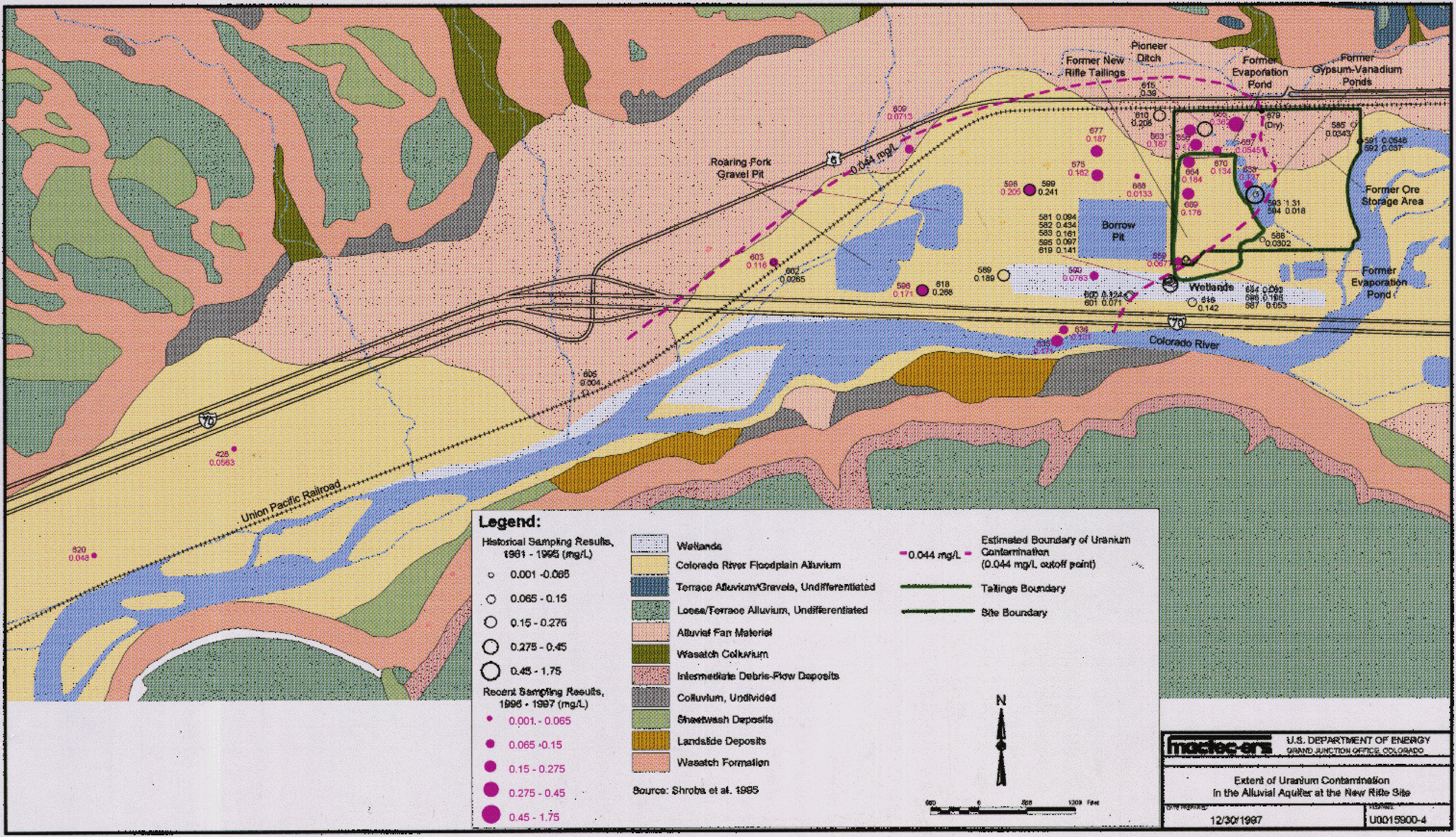


Figure 4–4. Extent of Uranium Contamination in the Alluvial Aquifer at the New Rifle Site

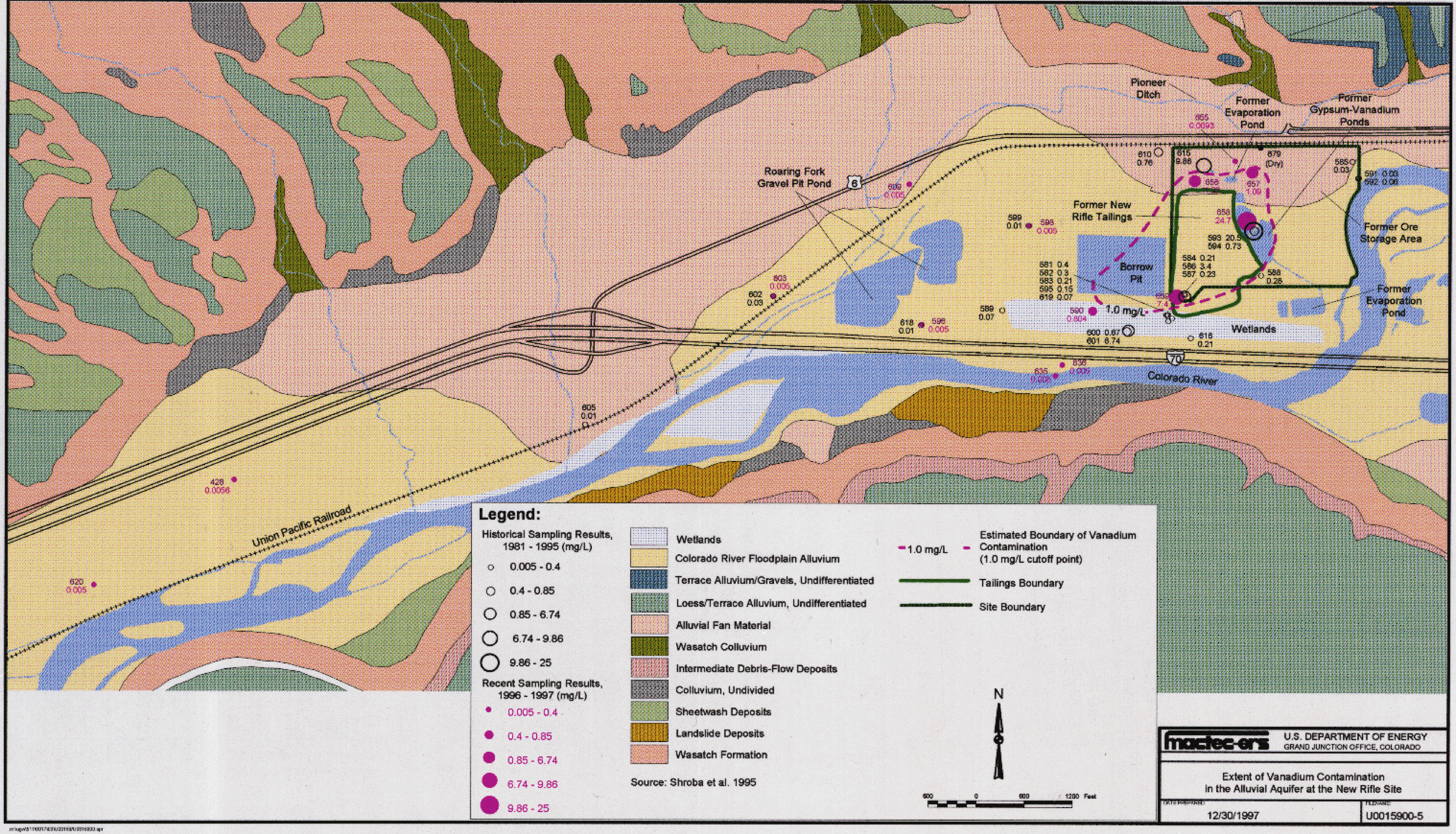


Figure 4–5. Extent of Vanadium Contamination in Alluvial Aquifer at the New Rifle Site

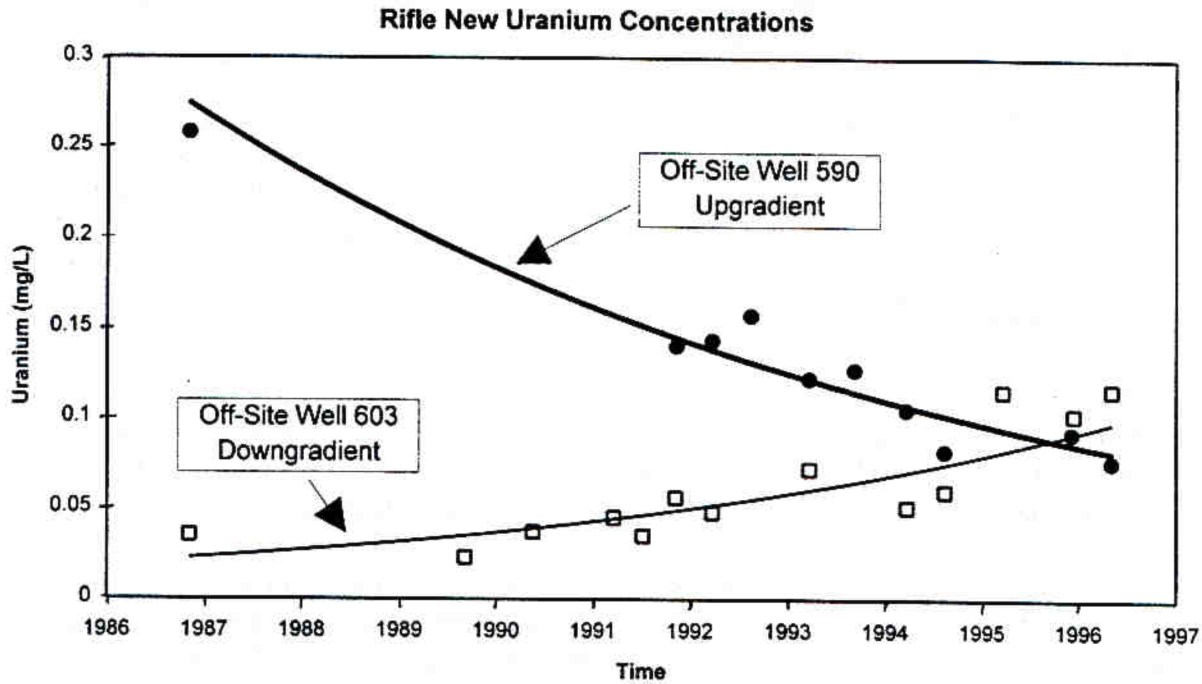


Figure 4–6. Uranium Concentrations Versus Time for Selected Off-Site Monitor Wells at the New Rifle Site

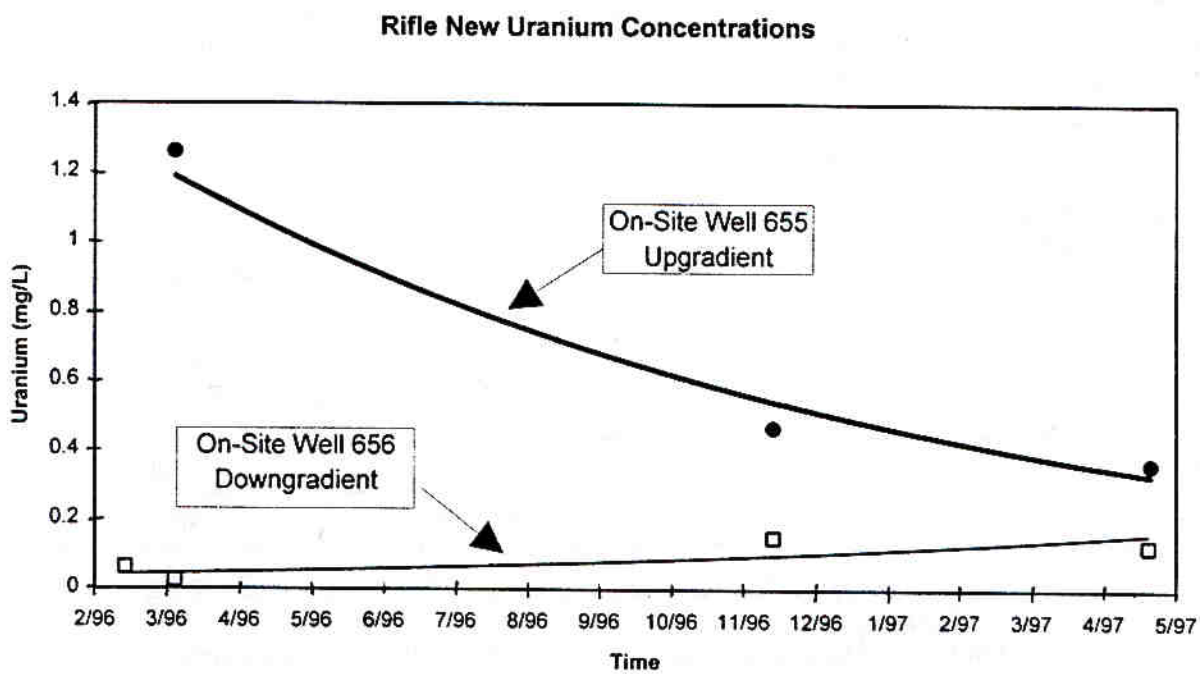


Figure 4–8. Uranium Concentration Versus Time for Selected On-Site Monitor Wells at the New Rifle Site

well RFN–656 appear to be increasing. The general distribution of the on-site monitor wells that tend to have either decreasing or increasing uranium concentrations in ground water is shown in Figure 4–7. Other indicator constituents such as ammonium and nitrate show a similar relative relationship to upgradient and downgradient concentrations.

The more recent plume migration suggests that tailings-related constituents may have been mobilized when the surface remediation was in progress. Perhaps water-soluble constituents in the tailings were mobilized by construction water applied during the surface remediation and by irrigation during the reseeding operation at the conclusion of the surface remediation.

4.5 Bedrock Aquifer Contamination

Ground-water contamination at the New Rifle site is more extensive in the shallow, unconfined alluvial/colluvial aquifer than in the deeper unweathered portion of the Wasatch bedrock. The upper, weathered portion of the bedrock is considered part of the shallow unconfined aquifer because it is in direct hydrologic contact with the alluvial/colluvial flow system.

Contaminants in the alluvial/colluvial ground water do not appear to have migrated to the deeper confined and semiconfined Wasatch aquifer, which is separated from the upper unconfined aquifer by a series of mudstone and shale aquitards. Water samples were collected from five nested Wasatch monitor wells (RFN–623, –624, –627, –628 and –629), which are within a 100-ft radius near the downgradient edge of the former tailings pile (Figure 4–9). Each well is screened at a different depth interval. Results of uranium analyses from ground-water samples collected from the five wells are summarized in Table 4–3 in order of increasing screen depth. The UMTRA MCL of 0.044 mg/L is exceeded only in monitor well RFN–624. The top of the screened interval for this well begins at the base of the alluvium and extends 10 ft into the uppermost portion of the Wasatch. Uranium concentrations decrease significantly (an order of magnitude) in well RFN–629, which is screened below the screened interval of well RFN–624. Concentrations decrease with screen depth in adjacent wells RFN–623, –627 and –628.

Table 4–3. Uranium Concentrations in Five Nested Wasatch Monitor Wells

Monitor Well	Date Sampled	Screened Interval (feet below ground level)	Uranium Concentration (mg/L)
624	3/94	29 – 39	0.137
629	3/92	45 – 55	0.014
623	11/92	46 – 66	0.001
627	3/92	67 – 87	0.010
628	10/92	93 – 113	0.001

Results of uranium analyses in Wasatch monitor wells at the Old Rifle site are shown in Figure 4–10. However, the number of monitor wells in the Wasatch Formation is insufficient to adequately characterize contaminant distributions.

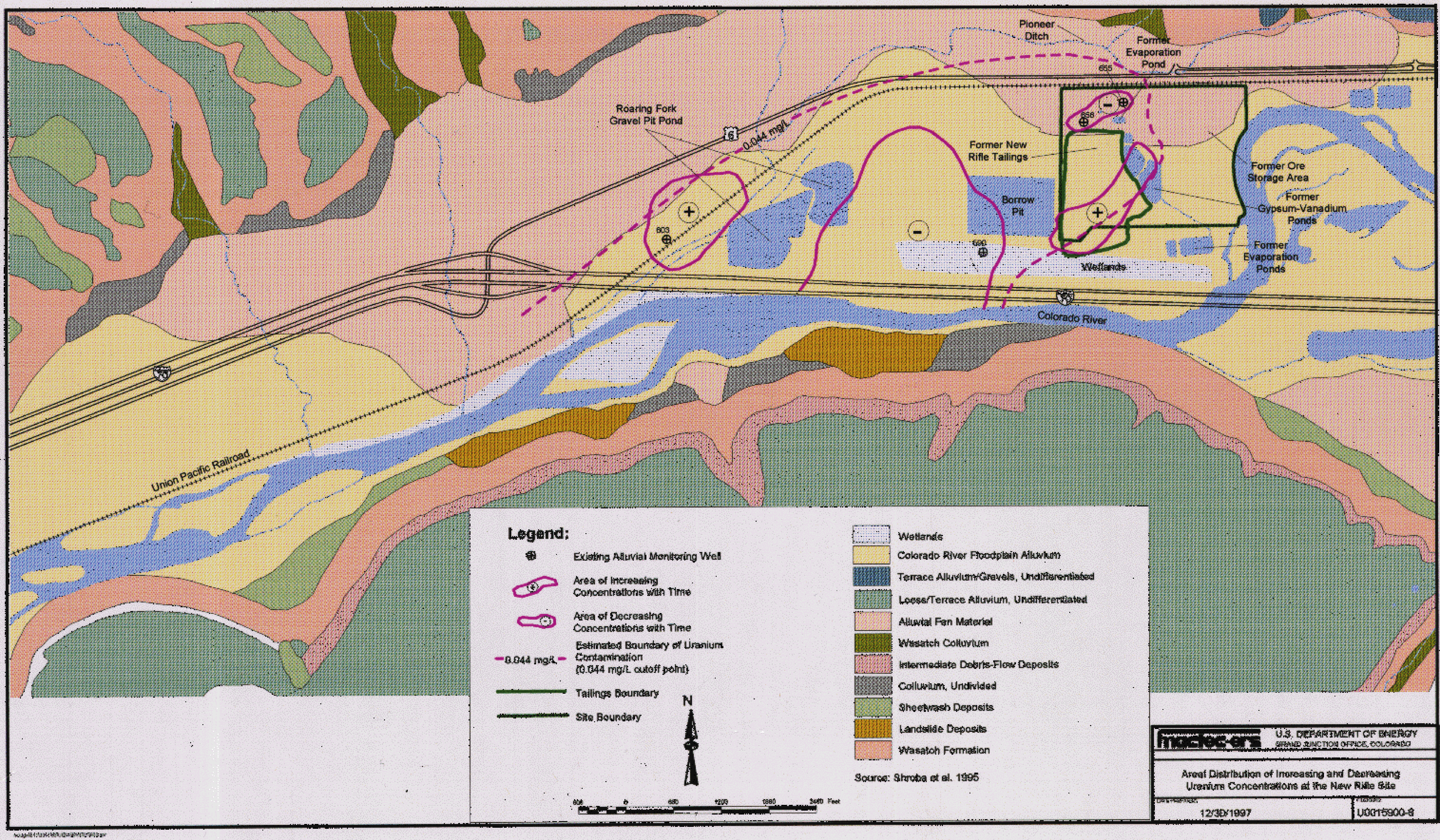


Figure 4–7. Areal Distribution of Increasing and Decreasing Uranium Concentrations at the New Rifle Site

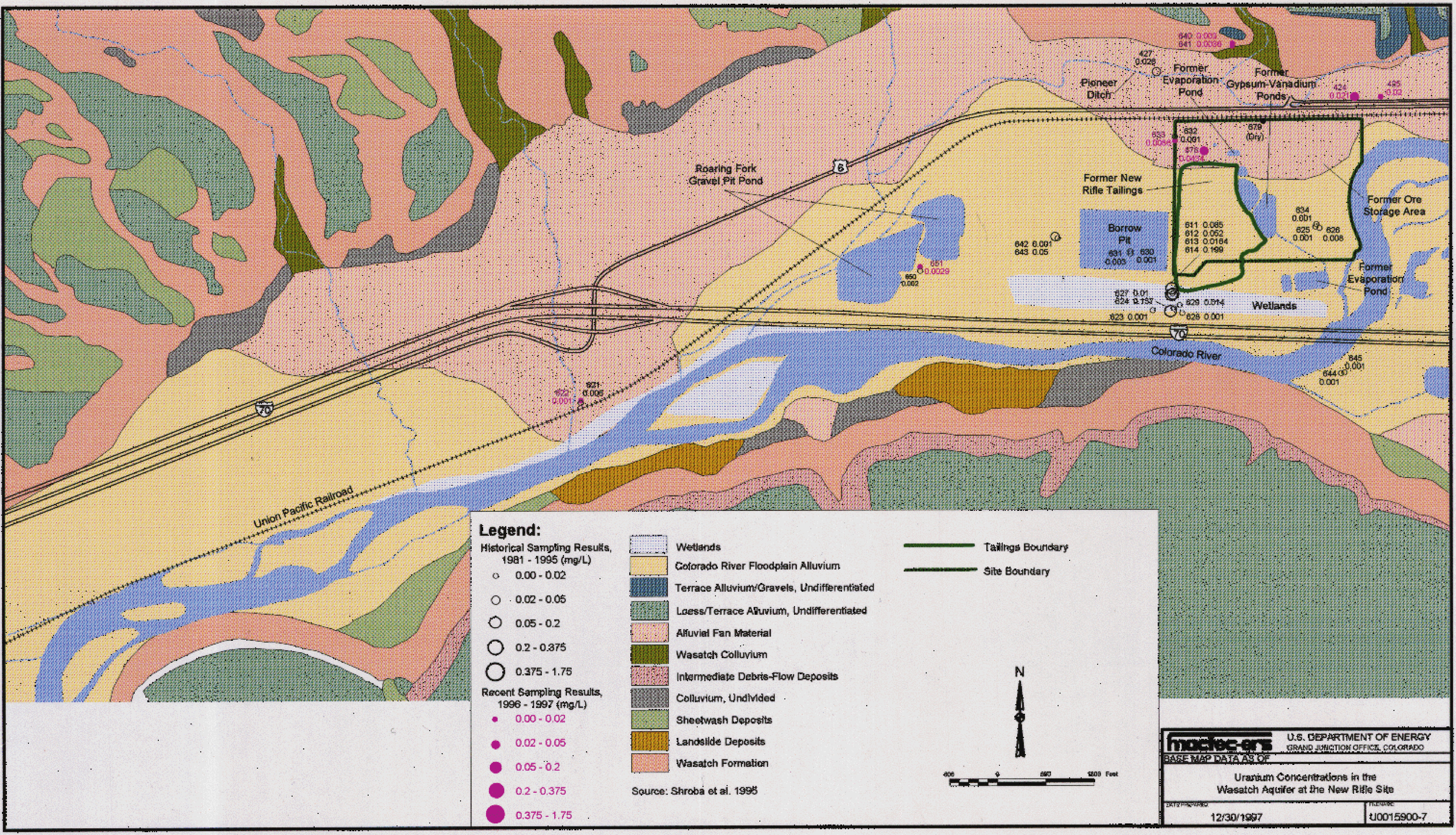


Figure 4–9. Uranium Concentrations in the Wasatch Aquifer at the New Rifle Site

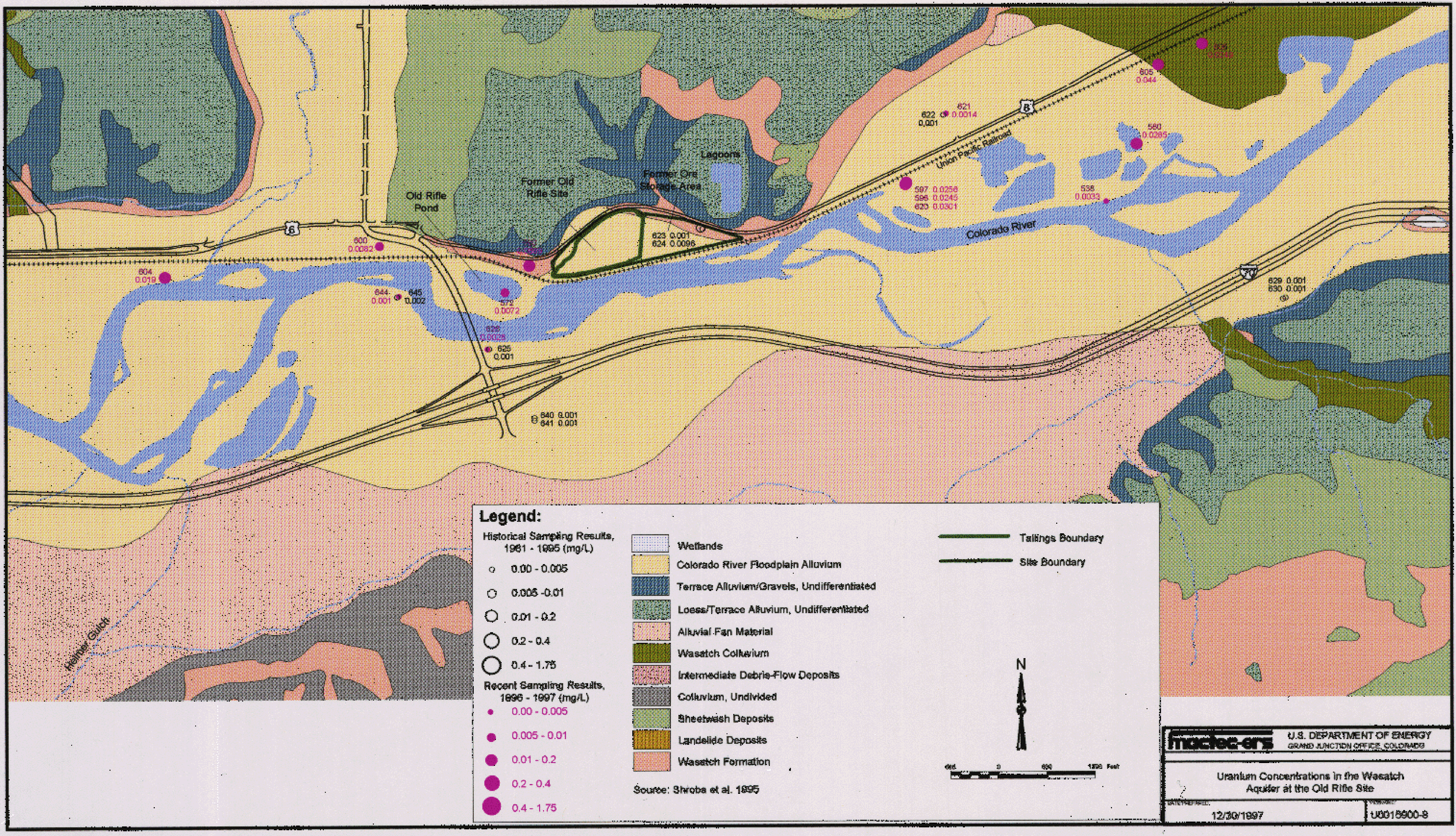


Figure 4–10. Uranium Concentrations in the Wasatch Aquifer at the Old Rifle Site

4.6 Surface-Water Contamination

Results of uranium analyses of surface-water samples collected periodically at three Colorado River locations and at three ponds from 1987 through 1997 are summarized in Table 4–4. Sample locations are presented in Figure 4–11.

Uranium concentrations at background river-sample location 538, which is upstream from the Old Rifle site, average 0.0035 mg/L. This value is consistent with the average concentration of 0.0035 mg/L in samples collected at location 545, which is downstream from the Old Rifle site. Uranium concentrations in river-water samples at location 548 downstream from the New Rifle site average 0.002 mg/L, which is less than the upstream background concentrations. These values indicate that neither site contributes uranium to the Colorado River. Concentrations of other trace elements in downstream river samples are similar to concentrations in upstream samples, which suggests that any contaminated ground water entering the Colorado River is diluted to background levels.

Table 4–4. Uranium Concentrations in Surface Waters

Location Number	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
River Samples (mg/L)											
538 (upstream from Old Rifle)	0.003				0.005			0.003		0.003	
545 (downstream from Old Rifle; upstream from New Rifle)	0.003				0.007		0.003 0.002	0.003		0.003	
548 (downstream from New Rifle)					0.001			0.003		0.003	
Pond Samples (mg/L)											
570 and 580 (One Mile Pond, upgradient from Old Rifle)								0.010 0.038		0.029[a]	
572 (Old Rifle Pond, downgradient from Old Rifle)			0.044	0.042	0.052	0.008 0.038	0.028 0.007	0.017	0.024	0.012 0.007	
575 (Roaring Fork gravel pit, downgradient from New Rifle)					0.435	0.030 0.362 0.421	0.214 0.365	0.311 0.30	0.269	0.157 0.185	0.168

[a]This sample was collected at location 580 from a pond located approximately 2,400 ft east (upgradient) of the 1994 One Mile Pond sample location 570.

Background pond and wetland waters have higher and more variable concentrations of trace elements than river waters. For example, the average uranium concentration of 0.026 mg/L obtained at background pond locations 570 and 580 is approximately seven times greater than the average concentration of 0.0035 mg/L obtained at the background river-water location 538. The average uranium concentration of 0.026 mg/L in background pond water is more consistent with the range in natural background of 0.017 to 0.046 mg/L obtained for alluvial ground water (Table 4–2). Thus, the higher concentrations in pond waters reflect the influence of recharge from the alluvial ground-water system. In cases where high concentrations of uranium in the pond waters correspond to high concentrations of other trace elements, variations in concentrations are attributed to different degrees of evaporation.

Relatively high concentrations of uranium may also be the result of contaminated ground-water recharging ponds and wetlands, as exemplified by the relatively high uranium concentrations measured at the Roaring Fork gravel pit (location 575). Uranium values at that location, downgradient from the New Rifle site, ranged from 0.435 mg/L in 1991 to 0.168 mg/L in 1997. These values are approximately one order of magnitude higher than the concentrations measured at One Mile Pond (background locations 570 and 580). The higher concentrations suggest that contaminated alluvial ground water from the New Rifle site is affecting the water quality at the Roaring Fork gravel pit. However, the uranium concentrations appear to be decreasing with time, as illustrated in Figure 4–12.

Analysis of samples from these surface-water sites will continue as part of routine monitoring. No additional data are required.

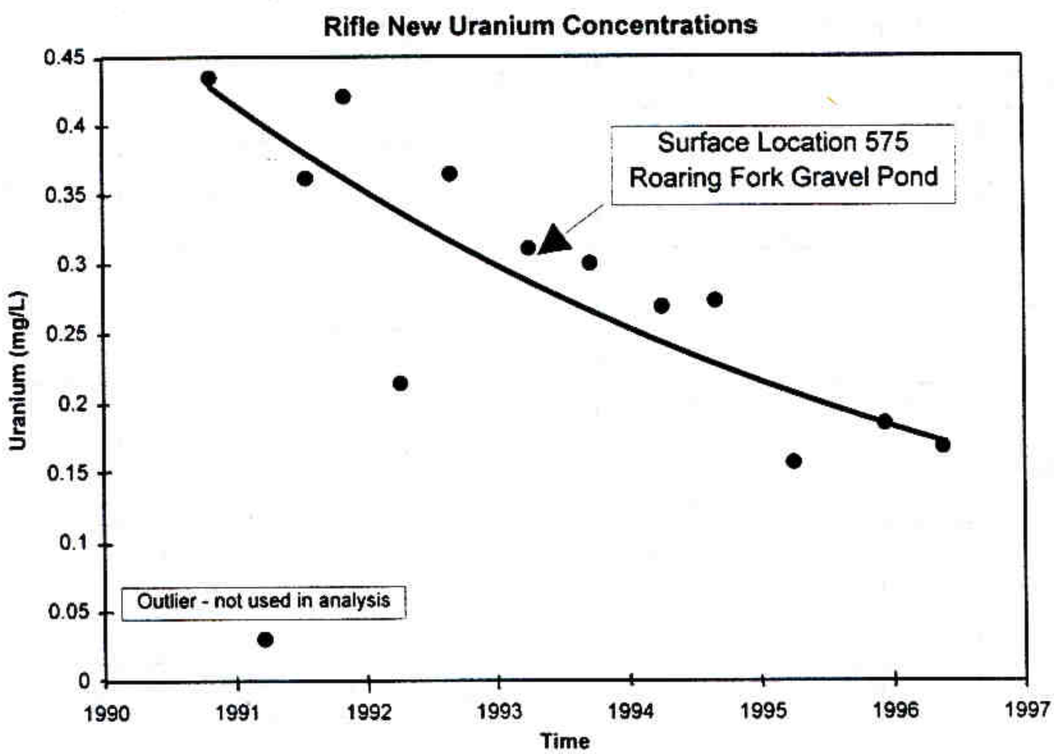


Figure 4–12. Uranium Concentrations in the Roaring Fork Gravel Pond Located Downgradient from the New Rifle Site

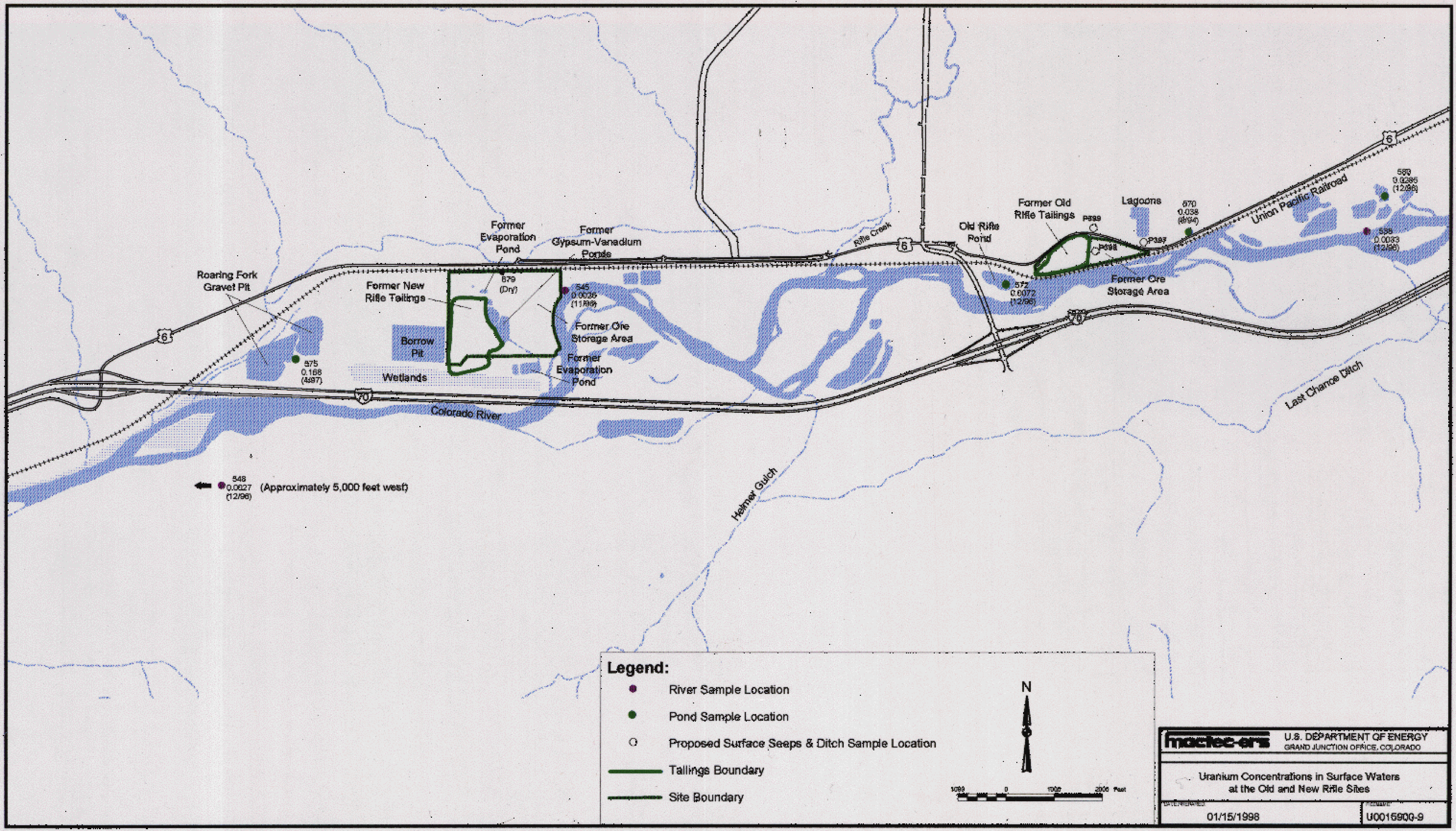


Figure 4–11. Uranium Concentrations in Surface Water at the Old and New Rifle Sites

4.7 Summary of Geochemical Data Needs

Additional geochemical data are needed at both the New and Old Rifle sites to adequately characterize the current contaminant distribution in the alluvial and bedrock flow systems.

4.7.1 Source Area Characterization

Soil samples need to be collected from the locations of each of the former tailings piles and evaporation ponds to determine if a continuing source of contamination exists. Leachate studies on the subpile soil samples need to be performed to determine if the solids hold a source of contamination that could be released into the ground water.

4.7.2 Monitor Well Network

The existing monitor well network, in both the alluvium and bedrock formation at the New Rifle and Old Rifle sites, needs to be expanded. New monitor wells should be installed in the former source areas and downgradient from the sites to characterize more fully the extent and nature of ground-water contamination. The nature of ground-water quality near downgradient wells RFN–620 and –428 at the New Rifle site and downgradient well RFO–590 at the Old Rifle site needs to be defined in greater detail. Selected Wasatch monitor wells that were removed during the surface remediation should be replaced to allow comparison to historical data. To ensure that wells are not completed in locations where the presence of residual tailing could bias sampling results, new monitor wells should not be installed on former vicinity properties.

5.0 Ecology

Characterization of the ecology of the former millsites at Rifle and the surrounding areas is needed to complete the assessment of ecological risks associated with site-related contaminated ground water. A defensible ecological risk assessment will support the development of risk-based compliance strategies.

The purpose of an ecological risk assessment is to evaluate the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to contamination or other stressors (EPA 1996). For ecological risks to occur at the Rifle site, pathways must exist for exposure of biological receptors to contaminated ground water. Screening-level assessments of ecological risks at the site evaluated COPCs, potential pathways, receptors, and adverse effects (DOE 1996b). This section summarizes the results of the screening-level assessment and identifies ecological characterization activities needed to complete the risk assessment.

5.1 Summary of the Screening-Level Risk Assessment

The screening-level risk assessment evaluated the potential exposure of terrestrial and aquatic organisms to contaminated ground water and to surface water or sediment contaminated by ground water. Concentrations of COPCs in ground water, surface water, and sediment were compared to toxicity standards and guidelines for various ecological receptors.

5.1.1 Ecological Contaminants of Potential Concern

Ecological COPCs were defined in the screening-level risk assessments as those constituents that statistically exceeded background concentrations (Table 5–1). Background ground-water quality was defined as the quality of ground water that would exist if milling had not taken place. The water quality in alluvial aquifer wells upgradient of the Old Rifle site was considered to be representative of background conditions (DOE 1996b). A constituent in the alluvial aquifer was included on the list of ecological COPCs if the on-site concentration statistically exceeded the background concentration at the 0.10 significance level (DOE 1995b).

Two categories of surface water were defined: Colorado River water and water in ponds near the Rifle sites (DOE 1996b). Colorado River COPCs were those constituents with statistically higher concentrations downstream of the millsites than upstream. Water quality in ponds near the Rifle sites (Old Rifle pond and Roaring Fork gravel pit pond) was compared to water quality in a background pond (One Mile Pond, sampling location 580, Figure 4–11). Similarly, ecological COPCs in sediments were determined by comparing upstream sediments with downstream sediments and on-site pond sediments with One Mile Pond sediments.

A 9.4-acre wetlands area was constructed in the southwest portion of the New Rifle site as an effort to recover 0.7 and 10 acres of wetlands that were lost during cleanup of the Old and New Rifle sites, respectively. Construction of the “mitigation wetlands” was a stipulation in the Section 404 Permit issued by the U.S. Army Corps of Engineers before remedial action began. The wetland was constructed after completion of the BLRA—wetland water, sediment, and biota have not been sampled. Because the contaminated alluvial aquifer is the primary water source for the mitigation wetland, water quality data from alluvial aquifer wells at the New Rifle site were used to develop a list of ecological COPCs for the wetland (DOE 1996e). Therefore, until baseline field investigations and monitoring of the mitigation wetland begin, the water quality of the New Rifle alluvial aquifer will be used to evaluate ecological risks in the wetland.

Table 5–1. Summary of Ecological Contaminants of Potential Concern in Ground Water, Surface Water, and Sediments

Constituents Above Background[a]	Old Rifle Ground Water	New Rifle Ground Water[b]	Colorado River Surface Water	Colorado River and Pond Sediment
Ammonium	X	X	X	
Arsenic	X	X		X
Cadmium		X		X
Calcium	X			
Chloride				
Fluoride	X	X		
Iron	X	X	X	X
Magnesium	X			
Manganese	X	X		X
Molybdenum	X	X		X
Nitrate		X		
Phosphate	X	X		
Potassium		X		
Selenium	X	X		X
Silica	X	X		
Sodium				
Strontium	X	X		
Sulfate	X	X		
Uranium	X	X		X
Vanadium	X	X		X
Zinc		X		X

[a]Greater than concentrations in a reference area (e.g., upgradient well, upriver surface water, or upgradient pond) at the 99 percent confidence level.
[b]Because the alluvial aquifer feeds the new mitigation wetland, alluvial aquifer water quality data were used to evaluate potential adverse effects to wetland ecology.

5.1.2 Potential Receptors

This section summarizes information on ecological receptors that are potentially exposed to ecological COPCs. The information was derived from qualitative surveys, observations, and previous reports such as the Rifle Environmental Impact Statement (EIS) (DOE 1990) and revegetation specifications (Morrison Knudsen Corporation 1996). The revegetation specifications document the planned vegetation. The ecology of the site before the remedial action and the ecology of nearby reference areas provide clues as to the types of vegetation natural and anthropogenic succession may eventually produce.

Potential Terrestrial Receptors

A history of milling activities and the recent remediation greatly disturbed the ecology of the Old and New Rifle sites. Before remediation, vegetation at the 22-acre Old Rifle site consisted primarily of grasses and forbs with some scattered Russian olive, greasewood, and cottonwood (DOE 1990). Cattail and willow grew along a drainage ditch that crossed the site. Salt cedar, alder, rabbitbrush, and sagebrush grew in nearby, less-disturbed riparian and upland areas. According to seeding specifications for the surface remedial action (Morrison Knudsen Corporation 1996), the Old Rifle processing site was planted with a mixture of western and tall wheatgrasses.

Before remediation, most of the 142-acre New Rifle site was covered with tailings piles. Wetlands habitat occurred on the southeast portion of the site. Three wetland plant communities were delineated: a shrub wetland dominated by salt cedar and willow; an emergent wetland dominated by cattails, sedges, and reed grass; and a saltgrass-dominated meadow (DOE 1996b). Vegetation on the open land just west of the site consisted of saltgrass with a few salt cedars in low-lying areas and a shrub-grass community in slightly elevated areas. The more common shrubs were black greasewood, rabbitbrush, and sagebrush; a mixture of brome grass and wheatgrasses dominated the understory. Dense stands of Russian thistle and knapweed grew around the Roaring Fork gravel pit area west of the site. The seeding specification prescribed three different mixtures for the New Rifle site: western wheatgrass and tall wheatgrass in the processing area; alkali sacaton, alkali grass, and creeping foxtail in a slightly lower wetland meadow area; and Great Basin wildrye, Indian ricegrass, and alkali sacaton in a buffer area between the processing area and the wetland area (Morrison Knudsen Corporation 1996).

Lists of potential wildlife receptors at the Old and New Rifle sites (Tables 5–2 and 5–3) are based on observations before remediation and on species expected to be attracted to the habitats created. A few of these species have been observed at the site. Most were included after a review of applicable literature (Hammerson 1986; Van Velzen 1980).

Potential Aquatic Receptors

No thorough surveys of aquatic organisms in surface-water bodies near the Rifle sites have been conducted. However, the following organisms were observed in the wetland ditch at the New Rifle site before the remedial action: water striders, backswimmers, mosquito larvae, and midge larvae (DOE 1996b). Game fish known to inhabit the area include green sunfish, black bullhead, brown trout, and rainbow trout. Bluehead sucker, flannelmouth sucker, common carp, roundtail chub, and fathead minnow also occur in the area.

Table 5–2. Mammals, Amphibians, and Reptiles Expected to Inhabit the Mitigation Wetlands at the New Rifle Site

Mammals	**Amphibians and Reptiles**
Muskrat	Woodhouse toad
Raccoon	Northern leopard frog
Mule deer	Racer
Rabbits	Corn snake
Hares	Bullsnake
Vole species	Western terrestrial garter snake
Mice species	

Table 5–*3. Breeding Birds That May Nest in the Mitigation Wetlands at the New Rifle Site*

Pied-Billed Greb	Killdeer	American Robin
Great Blue Heron	Common Snipe	European Starling
Black-Crowned Night Heron	Spotted Sandpiper	Yellow Warbler
Canada Goose	Common Nighthawk	Common Yellowthroat
Mallard	Belted Kingfisher	Yellow-Breasted Chat
Gadwall	Western Kingbird	Green-Tailed Towhee
Pintail	Say’s Phoebe	Rufus-Sided Towhee
Green-Winged Teal	Willow Flycatcher	Savannah Sparrow
Blue-Winged Teal	Olive-Sided Flycatcher	Chipping Sparrow
Cinnamon Teal	Barn Swallow	Song Sparrow
American Widgeon	Cliff Swallow	Yellow-Headed Blackbird
Common Merganser	Black-Billed Magpie	Red-Winged Blackbird
Northern Harrier	Common Crow	Northern Oriole
American Kestrel	Dipper	Brewer’s Blackbird
Virginia Rail	Bewick’s Wren	Black-Headed Grosbeak
Sora	Northern Mockingbird	American Goldfinch
American Koot	Gray Catbird	Lesser Goldfinch

Threatened and Endangered Species

Federally listed threatened and endangered (T&E) species are given special treatment as potential receptors (EPA 1996a). Whereas for most receptors, toxicity benchmarks used in risk calculations give a measure of the potential effect on population sustainability, benchmarks used for T&E species produce measures of toxicity to individuals. At the time the Rifle EIS was published, the bald eagle and the razorback sucker were the only T&E species that occurred regularly near the Rifle sites (DOE 1990). Bald eagles winter along the Rifle reach of the Colorado River and sometimes nest a few miles upriver from the Old Rifle site. Razorback suckers inhabit the Colorado River near both Rifle sites.

5.1.3 Potential Adverse Effects

The screening-level risk assessment for Rifle addressed the following potential pathways:

- Plant uptake of ground water.
- Agricultural use of ground water, pond water, and Colorado River water.
- Exposure of aquatic life in Colorado River water and sediments.
- Exposure of terrestrial and aquatic life in ground-water-fed ponds and wetlands.

Plant Uptake of Alluvial Ground Water

Plant species and plant communities can be adversely affected if exposed to contaminated ground water taken up through roots. Wildlife that bioaccumulate certain contaminants could also be adversely affected by ingesting vegetation. Phreatophytes including cottonwood, salt cedar, willow, and greasewood—plants that have the potential to root into the shallow alluvial aquifer—will likely continue to inhabit both Rifle sites. The potential for phytotoxic effects was evaluated by comparing alluvial ground-water concentrations to published benchmark concentrations that can result in phytotoxicity (Will and Suter 1994). These screening-level comparisons indicate that arsenic, cadmium, molybdenum, and vanadium concentrations in the alluvial aquifer exceed the published benchmarks. This does not necessarily indicate that phytotoxic responses or animal toxicity will occur; plant-to-water concentration ratios are typically less than one. Vegetation sampling is warranted to determine if phreatophyte tissue concentrations actually exceed phytotoxicity benchmarks.

Agricultural Use of Ground Water and Surface Water

Ground water and some pond water at the Rifle sites may be toxic if used to water livestock or to irrigate crops. Concentrations of cadmium, fluoride, molybdenum, selenium, and vanadium in the alluvial aquifer at both sites exceed toxicity benchmarks for livestock watering and crop irrigation (DOE 1995b). Nitrate and sulfate concentrations in the alluvial aquifer exceed the livestock water benchmark. The high sodium absorption ratio would preclude the use of ground water for crop irrigation (DOE 1995b).

Concentrations of molybdenum, nitrate, and sulfate in the Roaring Fork gravel pond all exceed toxicity benchmarks for livestock watering. Concentrations of COPCs in the Old Rifle pond did not exceed agricultural benchmarks. The pond in the mitigation wetland area may have the highest concentrations of COPCs because the pond is fed directly by the contaminated alluvial aquifer; however, currently no water quality data exist for the wetlands.

Concentrations of COPCs in Colorado River water potentially affected by the sites are below agricultural toxicity benchmarks (DOE 1995b).

Aquatic Organisms in Colorado River Water and Sediments

Levels of ecological COPCs in Colorado River water and sediments were less than aquatic life criteria and sediment screening benchmarks (DOE 1995b).

Terrestrial and Aquatic Life in Ponds and Wetlands

Concentrations of ecological COPCs in Old Rifle pond water and Roaring Fork gravel pit pond water were below aquatic life criteria. Arsenic, cadmium and zinc concentrations exceed sediment screening benchmarks in Old Rifle pond; site-related contamination may have adverse effects on benthic and other aquatic organisms that inhabit the pond. Sediments in the Roaring Fork gravel pit pond have not been sampled.

Analysis of alluvial aquifer water in the area of the mitigation wetland before its construction indicated that of the 20 ecological COPCs, cadmium, iron, manganese, selenium, and vanadium concentrations exceeded toxicity benchmarks for terrestrial and aquatic organisms that were expected to inhabit the wetland. Cadmium, iron, and manganese concentrations exceeded the aquatic life criteria for chronic effects. It is expected that manganese levels and toxicity responses will increase with time. Selenium levels in the alluvial aquifer exceed aquatic life criteria for both chronic and acute effects. Selenium levels in water entering the wetlands may exceed 0.2 mg/L. At this level, bioaccumulation of selenium in plants and aquatic invertebrates could result in complete reproductive failure and mortality in many species of marsh birds (Ohlendorf 1989). Although there are no State or Federal aquatic life criteria for vanadium, levels in the alluvial aquifer may also result in chronic effects (Suter and Mabrey 1994).

5.2 Summary of Ecological Data Needs

The screening-level risk assessment for Rifle (DOE 1995a, 1995b) suggests that adverse ecological effects may occur if (1) plants root into the contaminated alluvial aquifer, (2) alluvial aquifer water contaminates the mitigation wetland, and (3) alluvial aquifer water or pond water is pumped to water livestock or to irrigate crops. Pathways currently exist for the first two exposure scenarios. Phreatophytes have established on the sites and construction of the mitigation wetland is complete. There are no existing agricultural uses of contaminated ground water or pond water (DOE 1996b).

The following ecological characterization activities are needed to evaluate these exposure pathways potential adverse ecological effects:

- Meet with Garfield County and City of Rifle officials to determine possible future land use of both the Old and New Rifle sites. Discuss measures to prevent use of the contaminated alluvial aquifer for crop irrigation or livestock watering. Evaluate ecological risks of any other potential land uses.

- Establish geological, hydrological and ecological criteria to select ecological reference areas for (1) phreatophyte habitat at both the Old and New Rifle sites, (2) pond sediment at the Old Rifle pond and the Roaring Fork gravel pit pond, and (3) the mitigation wetland. Conduct a reconnaissance for reference areas.

- Characterize current and possible future plant ecology (use reference areas to infer possible future plant ecology) overlying the contaminated alluvial aquifers at the Old and New Rifle sites. Identify phreatophyte species rooted into the portion of the plume with the highest contaminant concentrations. Project changes in plant ecology given possible future land-use scenarios.

- Sample and compare COPC concentrations in tissue taken from phreatophytes growing in the most contaminated on-site ground water and from phreatophytes growing in reference areas. Calculate incremental hazard indices (HIs) and HI ratios for toxicity to plants and animals (wildlife and livestock) that may ingest the contaminated vegetation.

- Sample and compare COPC levels in the Old Rifle pond, the Roaring Fork gravel pit pond, and the reference area ponds. Calculate incremental HIs and HI ratios for aquatic life. Characterize and sample aquatic life populations if the incremental risk is significant.

- Establish a monitoring program for water and sediment in the mitigation wetland at the New Rifle site to determine if contaminants in the alluvial aquifer reach the wetlands. Analytes should include the New Rifle ground-water COPCs (Table 5–1). Include a reference area wetland in the program. Collect baseline water and sediment data, calculate incremental HIs and HI ratios for aquatic life and terrestrial organisms, and expand the monitoring program to include terrestrial and aquatic receptors in the wetlands if HIs are significant.

6.0 Site Conceptual Model

The model presented in this section is taken from the SOWP (DOE 1996e) and represents a synthesis of geologic, hydrogeologic, and geochemical data that were derived from previous monitoring at the Old and New Rifle sites. Details of the conceptual model and supporting information are presented in Sections 2 through 4 of this work plan. The site conceptual model will be refined and improved as data needs are fulfilled by additional site characterization.

COPCs in ground water at the Rifle sites were identified in the BLRA (DOE 1996b) and are presented in Table 4S2 of this work plan. Several of the constituents were either not detected during the most recent sampling or were detected at concentrations that were below MCLs or health advisory limits. Those constituents are considered COPCs on the basis of concentrations detected previously in samples from wells that were later removed during the surface remediation. The list of COPCs may be revised after ground-water contamination at the sites has been more fully characterized.

Ground-water contamination at the Old and New Rifle sites is most likely a result of mill process water draining from the tailings piles and seeping from evaporation ponds and, to a lesser extent, a result of contaminants leaching from stockpiled ores. Contaminants released from the stockpiles of ore would have been relatively soluble components such as uranium, vanadium, selenium, arsenic, and molybdenum. Nitrate would not have been a significant constituent of the ores and would only have entered the ground water during the milling process.

6.1 Surface-Water Features

6.1.1 Old Rifle Site

Surface-water features include the Colorado River, Old Rifle pond, a drainage ditch extending north to south across the center of the site, surface runoff ditches located above the site on the north side of Highway 6, and detention lagoons used by the City of Rifle and located above the Old Rifle site on Graham Mesa. The Colorado River forms the southern boundary of the site and is the dominant surface-water feature; ultimately the river receives all surface-water drainage from the vicinity of the Old Rifle site.

6.1.2 New Rifle Site

Surface-water features at the New Rifle site include the Colorado River, the Roaring Fork gravel pit, the mitigation wetlands, a borrow pit ephemeral pond, the Pioneer irrigation ditch, and wastewater treatment ponds. As at the Old Rifle site, the Colorado River forms the southern boundary of the site and is the dominant surface-water feature. The river receives surface drainage from the vicinity of the New Rifle site. At both the New and Old Rifle sites, the river receives baseflow ground-water discharge during periods of low river flow that typically extend from July or August through February or March. During periods of spring runoff between March and June, high river flows exceed ground-water elevations in the alluvial aquifer and the river is temporarily a recharge source for alluvial ground water. It is likely that the north-south reach of the river just east of the New Rifle site is a source of alluvial ground-water recharge throughout the year.

6.2 Ground Water

Lithologic logs that support this conceptual model of the aquifer system were prepared from cuttings discharged during mud and air rotary drilling, and descriptions of the lithology may therefore be questionable. Lithologic descriptions and stratigraphic sequences will be more fully characterized during the planned installation of alluvial and bedrock monitor wells.

Analysis of ground-water level trends and ground-water quality data indicates that at least three flow systems are present near the Rifle sites. The upper system is north of the sites and results mainly from springs that discharge along bedding surfaces in upper stratigraphic levels of the Wasatch Formation. The second system (on site) is the alluvial aquifer. This system includes the colluvium and weathered uppermost 3 to 5 ft of Wasatch Formation that underlies the alluvium and colluvium at both sites. The third flow system consists of a confined and semiconfined aquifer in Wasatch Formation sandstones and shales beneath an aquitard of competent siltstones and shales.

6.2.1 Old Rifle Site

The extent of the alluvial aquifer at the Old Rifle site is largely limited to the site boundary, where narrow sections of alluvium extend eastward between the river and a Wasatch outcrop and westward past a prominent Wasatch outcrop toward Old Rifle pond. Thickness of the alluvial/colluvial deposits is about 20 to 25 ft over most of the site. Depths to ground water range from 10 to 17 ft on the site and 3 to 8 ft east and west of the site near the river. Saturated thickness ranges from 4 to 18 ft. Hydraulic conductivities estimated from slug test data range from 0.13 to 2.1 ft/day. These values are in the low end of the range for sands and gravels and may underestimate actual conductivities. Hydraulic gradients, directed west-southwest (Figure 3**S**1), are approximately 0.0045 ft/ft. Average linear velocities based on these estimates and an assumed porosity of 0.3 range from 0.7 to 11 ft/year.

The average linear ground-water velocity in the Wasatch Formation is 0.2 ft/year. Less than 500 ft southwest of the Old Rifle site, within the narrow floodplain between the Colorado River and the Old Rifle site, an outcrop of Wasatch bedrock slows ground-water flow, and its relatively low hydraulic conductivity forces alluvial ground-water flow toward the river.

6.2.2 New Rifle Site

The uppermost stratum of the alluvial aquifer consists of predominantly fine-grained alluvial floodplain deposits composed mostly of clays, silts, and fine-grained sands. The underlying stratum consists mostly of colluvial clayey/silty sands, gravels, cobbles, and blocks along the northern sections of the aquifer and of coarse-grained fluvial deposits along the southern section near the Colorado River. As at the Old Rifle site, the weathered surface of the Wasatch Formation beneath the New Rifle site is regarded as part of the alluvial flow system.

Thickness of the alluvial and colluvial sediments at the New Rifle site ranges from less than 20 ft to more than 80 ft. The shallowest deposits are along the river and near Roaring Fork gravel pit; the greatest thicknesses are north of the freeway interchange west of the site. Depths to ground water range from less than 3 ft to more than 60 ft; shallower depths are east of the site near the river and the greater depths are in the areas of thicker alluvial deposits west of Roaring Fork gravel pit. Saturated thickness ranges from 10 to 20 ft near the site.

Hydraulic conductivities determined from slug test data average abut 1 ft/day in the alluvium and 0.17 ft/day in the Wasatch Formation. Linear ground-water velocity ranges from about 1 to 10 ft/year in the alluvium. The average linear ground-water velocity in the Wasatch Formation is 2 ft/year. Limited test data, heterogeneity of the alluvial deposits, and sensitivity of the ground-water velocity to various parameters may result in considerable variations in calculated linear ground-water flow velocities at both the New and Old Rifle sites.

6.3 Ground-Water Quality

The chemical composition of ground water at both Rifle sites is influenced by several sources. The Colorado River is the regional discharge for ground water in the Wasatch Formation. Normally, flow in the Wasatch Formation near the river is upward into the alluvium; thus, flow systems in the deep Wasatch Formation influence water quality at the Rifle sites. Because the hydraulic gradient in the Wasatch is generally to the southwest in the vicinity of Rifle, flow systems in the upper Wasatch, north of and uphill from the sites, discharge to the alluvium in the vicinity of the sites. Depending on seasonal high and low river stages, ground-water quality in the alluvium at the Rifle sites is influenced by recharge from the river. Also, return irrigation flow makes a seasonal contribution to recharge of the uppermost aquifer at both sites. Water quality at the sites is influenced by precipitation and evapotranspiration that take place directly at each site.

Evaluation of both regional and site background data indicates that ground-water quality in the Rifle area is naturally variable and generally poor. Levels of several chemical constituents (e.g., barium, molybdenum, radium, selenium, and uranium) in regional and local background ground water have exceeded MCLs. Return irrigation flow masks this poor water quality in heavily irrigated areas upgradient of both Rifle sites.

Tailings leachate has migrated into the alluvium and constituents have subsequently migrated downgradient from each site. Most of the ground-water contamination at both Rifle sites appears to be in alluvial materials. The Old Rifle site is immediately adjacent to the Colorado River, and a Wasatch Formation escarpment extending toward the river directs the bulk of alluvial ground-water flow into the river. Thus, most contamination is confined to the processing and tailings site. However, evidence from ground-water quality data at the New Rifle site indicates that the interconnected zone consisting of weathered Wasatch Formation and the overlying alluvium may form a more permeable pathway than either unit alone. This interconnected zone may be the most contaminated zone at the New Rifle site. At both sites, some ground-water contamination is present in the upper few feet of the unweathered Wasatch Formation immediately beneath the weathered contact with the alluvium.

Alluvial contamination will likely eventually flush into the Colorado River. Limited data indicate that chemical constituents not affected by chemical interactions (e.g., sulfate and nitrate) may be flushed in as little as 10 years at the Old Rifle site and in as little as 50 years at the New Rifle site after removal of tailings. Contaminated ground water has the potential to enter surface water at both sites.

Data indicate that although ground water is discharging into the river and Old Rifle pond, the quality of the surface water is not discernibly affected. Surface-water quality in the Roaring Fork gravel pit pond west of the New Rifle site has been affected, as evidenced by elevated concentrations of several constituents.

The mitigation wetland at the New Rifle site is fed in part by contaminated alluvial ground water. Therefore, the evaluation of the wetland is based on ground-water concentrations rather than surface-water data from the wetland. However, several environmental factors will influence constituent concentrations in the mitigation wetland. These factors, which may increase or decrease surface-water contaminant concentrations, include rainfall, snow, evaporative effects, dilution by the river during high-flow stages, and geochemical processes in the wetland. Based on an evaluation of constituent concentrations in the ground water, four constituents (cadmium, iron, manganese, and selenium) exceed their respective State water-quality standards for the protection of aquatic life; chloride concentrations exceed the chronic Federal Water Quality Criterion considered protective of aquatic life (DOE 1996e).

7.0 Data Quality Objectives

The Data Quality Objective (DQO) process is "a scientific and legally defensible data collection planning process to help users decide what type, quality, and quantity of data will be sufficient for environmental decision making. DQOs are qualitative and quantitative statements derived from the outputs of each step of the DQO process that (1) clarify the study objective; (2) define the most appropriate type of data to collect; (3) determine the most appropriate conditions from which to collect the data; and (4) specify acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision" (EPA 1993).

DQOs are governed by the decisions necessary to determine appropriate responses at the Rifle sites and will be achieved through use of the procedures specified in Section 8.0. Specific DQOs for this project are summarized in Tables 7S1 and 7S2.

7.1 Data Quality Objectives at the Old Rifle Site

DQOs and data collection strategies specific to the Old Rifle site are presented in Table 7–1. The rationale for each DQO is discussed in Sections 7.3.1 through 7.3.7.

Table 7S1. Data Quality Objectives and Data Collection Strategies at the Old Rifle Site

Data Quality Objective—Old Rifle Site	Data Collection Strategy—Old Rifle Site
Characterize water quality of the alluvial aquifer.	C —Use temporary small diameter standpipes on site to measure water levels and to collect samples for field analyses at up to 10 locations. C —Install up to 13 monitoring wells (see Figure 7–1). —Five permanent 2-inch monitoring wells (P654, P655, P656, P657, P662) on site. —One 4-inch pumping well (P663) on site. —Two downgradient 2-inch monitoring wells (P652 and P653). —Two background 2-inch (upgradient) well pairs (P658/659and P660/661). —One 2-inch stilling well (P670). • Collect and analyze ground-water samples according to the procedures in Section 8.3; analyze for the COPCs listed in Table 4S2.
Characterize the lithology of unconsolidated alluvial/colluvial deposits from ground surface to competent bedrock of the Wasatch Formation.	Collect a 2-ft split barrel sample every 5 ft during drilling of permanent monitoring wells; log all auger cuttings.
Characterize contaminant sorption in the alluvial and Wasatch aquifer.	Measure distribution coefficients (Kd values) in saturated alluvium and Wasatch Formation. Kd measurements will be made on samples from background wells P658/659, on-site wells P655/656, downgradient alluvial well P652, and on-site Wasatch wells P648/649. To test samples of different lithologies, two samples will be collected from each selected location—In alluvial wells, one sample from near the surface of the water table and one from the lower zone of the alluvial aquifer; in Wasatch wells, one sample from 5–10 ft below the top of the Wasatch and one from 30–35 ft below the top of the Wasatch.

Table 7S1 (continued). Data Quality Objectives and Data Collection Strategies at the Old Rifle Site

Data Quality Objective—Old Rifle Site	Data Collection Strategy—Old Rifle Site
Characterize ground-water flow and contaminant migration rates in the alluvial aquifer.	Determine the hydrologic properties of the alluvial aquifer and ground water–surface water interactions at the Old Rifle site: • Map alluvial water table elevations using water level measurements and determine seasonal gain and loss in the alluvial aquifer: —Take measurements in 10 temporary standpipes. —Take manual measurements of water levels in all permanent wells monthly for 1 year. —Measure water levels using data loggers in selected wells every 4 hours for 1 year. • Conduct aquifer tests to estimate hydraulic conductivity in the alluvial aquifer. —Conduct slug tests in new wells as necessary. —Conduct pumping test in alluvial well P663; use P655 as an observation well. • Measure water levels in stilling well using data logger every 4 hours for 1 year. • Possibly conduct a natural-gradient tracer test to measure hydrodynamic dispersivity.
Characterize subpile soil to evaluate the potential for a continuing source of ground-water contamination.	Collect two soil samples from each of four borings (see Figure 7–1): two borings within the footprint of the former tailings pile (P654, P655), one boring in the former ore storage area (P656), and one boring in an upgradient background location (P661). In each on-site boring, collect one sample from native soil beneath the contact with backfill (placed after the tailings remedial action) and one sample from the unsaturated zone just above the water table. Analyze samples for COPCs listed in Table 4–2.
Characterize plant ecology and land use.	• Perform a qualitative survey of the composition and abundance of riparian plant communities on and near the site. • Collect tissue samples of plants rooted in water; analyze samples for ecological COPCs (Table 5S1, column 2).
Characterize contaminants in surface water and sediments.	• Collect surface water samples from locations shown in Figure 4S11; analyze the samples for the COPCs listed in Table 4S2. • Collect river and pond sediments from locations that have a high likelihood of ground-water discharge.
Characterize the upper portion of the Wasatch Formation and Wasatch aquifer.	• Conduct detailed geologic mapping along the western side of the site to define the extent of the Wasatch Formation outcrop (see Figure 7S1). • Install four new 4-inch wells consisting of two paired completions (P646/647, P648/649). Each pair will have an upper completion (about 17 ft into competent Wasatch) and a lower completion (about 37 ft into competent Wasatch). A typical completion diagram is shown in Figure 7–4. • Describe the lithology using drill core and cuttings from new Wasatch wells. • Conduct a pumping test in well P648; use P649, P655, and P663 as observation wells.

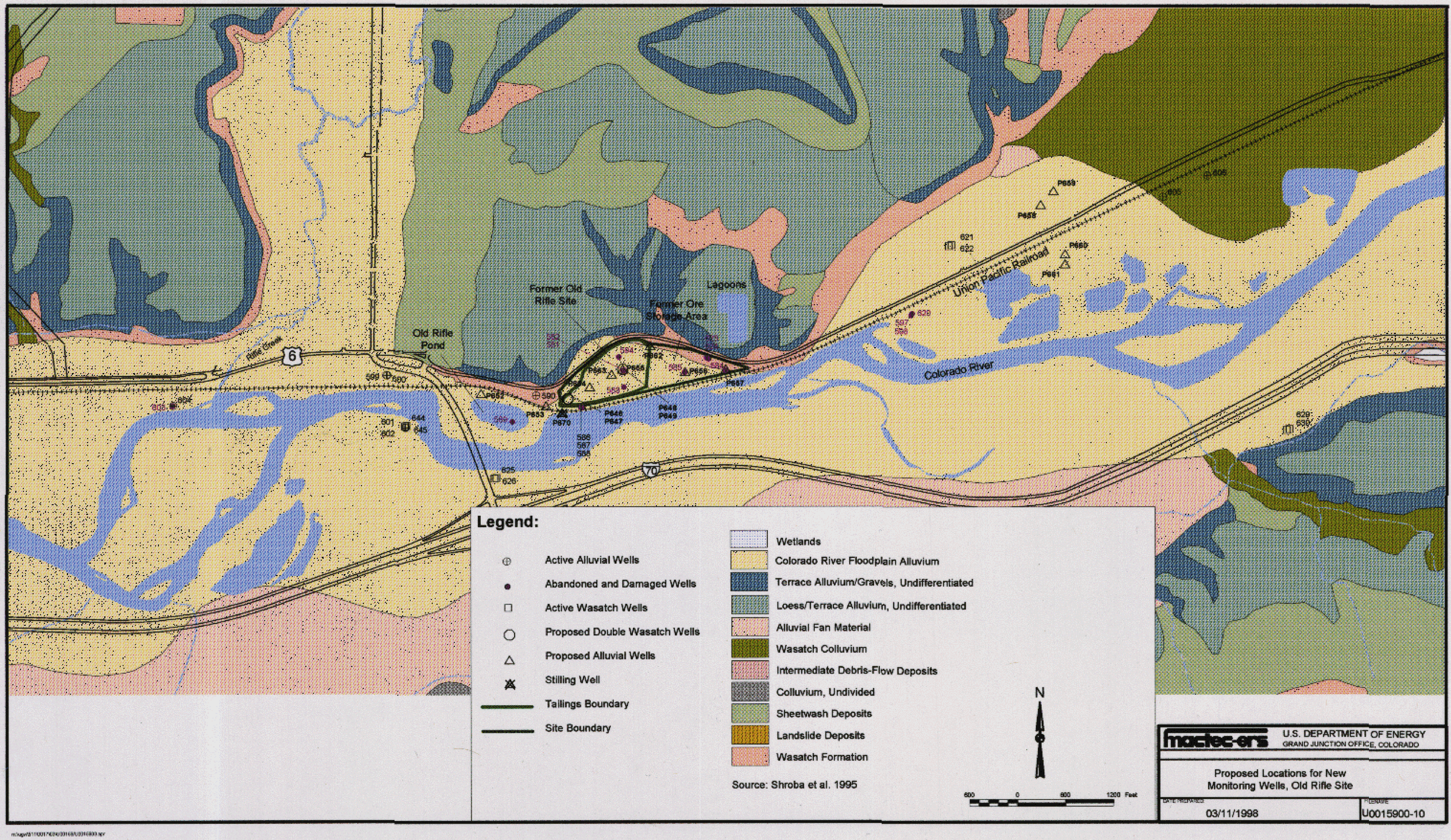


Figure 7–1. Proposed Locations for New Monitoring Wells, Old Rifle Site

7.2 Data Quality Objectives at the New Rifle Site

DQOs and data collection strategies specific for the New Rifle site are presented in Table 7–2. Sections 7.3.1 through 7.3.7 describe the rationale for each DQO.

Table 7S2. Data Quality Objectives and Data Collection Strategies at the New Rifle Site

Data Quality Objective—New Rifle Site	Data Collection Strategy—New Rifle Site
Characterize water quality in the alluvial aquifer.	• Use direct-push (Hydropunch) sampling method to collect alluvial ground-water samples for field measurements at up to 18 locations (see Figure 7S2) to determine the lateral and downgradient extent of the plume; Hydropunch sampling may also be performed at each of the five on-site wells, the five wells north of Highway 6, and the three downgradient wells to optimize the location of the alluvial monitoring well network. • Install up to 24 alluvial wells (see Figure 7S2): —Five 2-inch monitoring wells on and near the site (P215SP219). —Three 2-inch monitoring wells along the downgradient longitudinal extent of the plume (P210, P211, P220). —Five 2-inch monitoring wells (P170, P171, P212, P213, P214) north of Highway 6 to determine the lateral extent of mill-related contamination north of the site and to determine the potential contribution from naturally occurring upslope alluvium/colluvium. —Two 2-inch upgradient background monitoring well pairs (P168/P173, P169/P174). —One 2-inch downgradient background monitoring well (P172) approximately 3 mi downgradient from the site. —Three 4-inch pumping wells (P196, P200, P202), and three 2-inch observation wells (P201, P195, P197). • Install one 2-inch stilling well (P231). • Collect and analyze ground-water samples according to the procedures in Section 8.3.; analyze for the COPCs listed in Table 4S2.
Characterize the lithology of unconsolidated alluvial/colluvial deposits from ground surface to competent bedrock of the Wasatch Formation.	Collect a 2-ft split barrel sample every 5 ft during drilling of permanent monitoring wells; log all auger cuttings.
Characterize contaminant sorption in the alluvial and Wasatch aquifers.	Measure distribution coefficients (Kd values) in saturated alluvium and Wasatch. Kd measurements will be made on alluvial samples from three areas (Figure 7–2): upgradient background location P168, on-site location P219, and downgradient locations P200 and P210. Wasatch Formation Kd measurements will be made on samples from on-site location P205 and downgradient location P227 (Figure 7–3). To test samples of different lithologies, two samples will be collected from each location—In alluvial wells, one sample will be collected from near the surface of the water table and one will be collected from the lower zone of the alluvial aquifer; in Wasatch wells, one sample will be collected from 5–10 ft below the top of the Wasatch and one will be collected from 30–35 ft below the top of the Wasatch.

Table 7–2 (continued). Data Quality Objectives and Data Collection Strategies at the New Rifle Site

Data Quality Objective—New Rifle Site	**Data Collection Strategy—New Rifle Site**
Characterize ground-water flow and contaminant migration rates in the alluvial aquifer.	Determine the hydrologic properties of the alluvial aquifer at the New Rifle site: • Map alluvial water table elevations using water level measurements. —Measure water levels at selected Hydropunch locations. —Take manual measurements of water levels in all wells monthly for 1 year. —Measure water levels using data loggers in selected wells every 4 hours for 1 year. • Define seasonal gain and loss in the alluvial aquifer. • Conduct aquifer tests to estimate hydraulic conductivity in the alluvial aquifer. —Conduct slug tests in new wells as necessary. —Conduct pumping tests in alluvial wells P196, P200, P202; use P201, P195, and P197 as observation wells (see Figure 7**S**2). • Possibly conduct a natural-gradient tracer test to measure hydrodynamic dispersivity.
Characterize subpile soil to evaluate the potential for a continuing source of ground-water contamination.	Collect two soil samples from each of six borings (Figure 7**S**2): two borings in former evaporation ponds (P192, P216), two borings in the footprint of the former tailings pile (P218, P219), one boring upgradient of the pile footprint in the former ore storage area (P215), and one background boring upgradient (P168). In each boring, collect one sample from native soil beneath the contact with backfill (placed after the tailings remedial action) and one sample from the unsaturated zone just above the water table.
Characterize plant ecology and land use.	• Perform a qualitative survey of the composition and abundance of riparian plant communities on and near the site. • Collect tissue samples of plants rooted in water; analyze samples for ecological COPCs (Table 5**S**1, column 3).
Characterize contaminants in surface water and sediments.	• Collect surface-water samples from locations shown in Figure 4**S**11; analyze the samples for COPCs listed in Table 4**S**2. • Collect Colorado River and pond sediment samples at locations that have a high likelihood of ground-water discharge.
Characterize the upper portion of the Wasatch Formation and Wasatch aquifer.	• Install seven 4-inch Wasatch Formation wells (locations in Figure 7**S**3; typical completion diagrams in Figure 7**S**4): five shallow completions (P206, P207, P208, P226, P227, each about 17 ft into competent Wasatch Formation) and one well pair (P225, about 17 ft into competent Wasatch Formation; P205, about 37 ft into competent Wasatch Formation). • Conduct aquifer pumping tests: —Wells P206 and P227; use nearby existing Wasatch wells as observation wells. —Well P225; use P205 as an observation well.

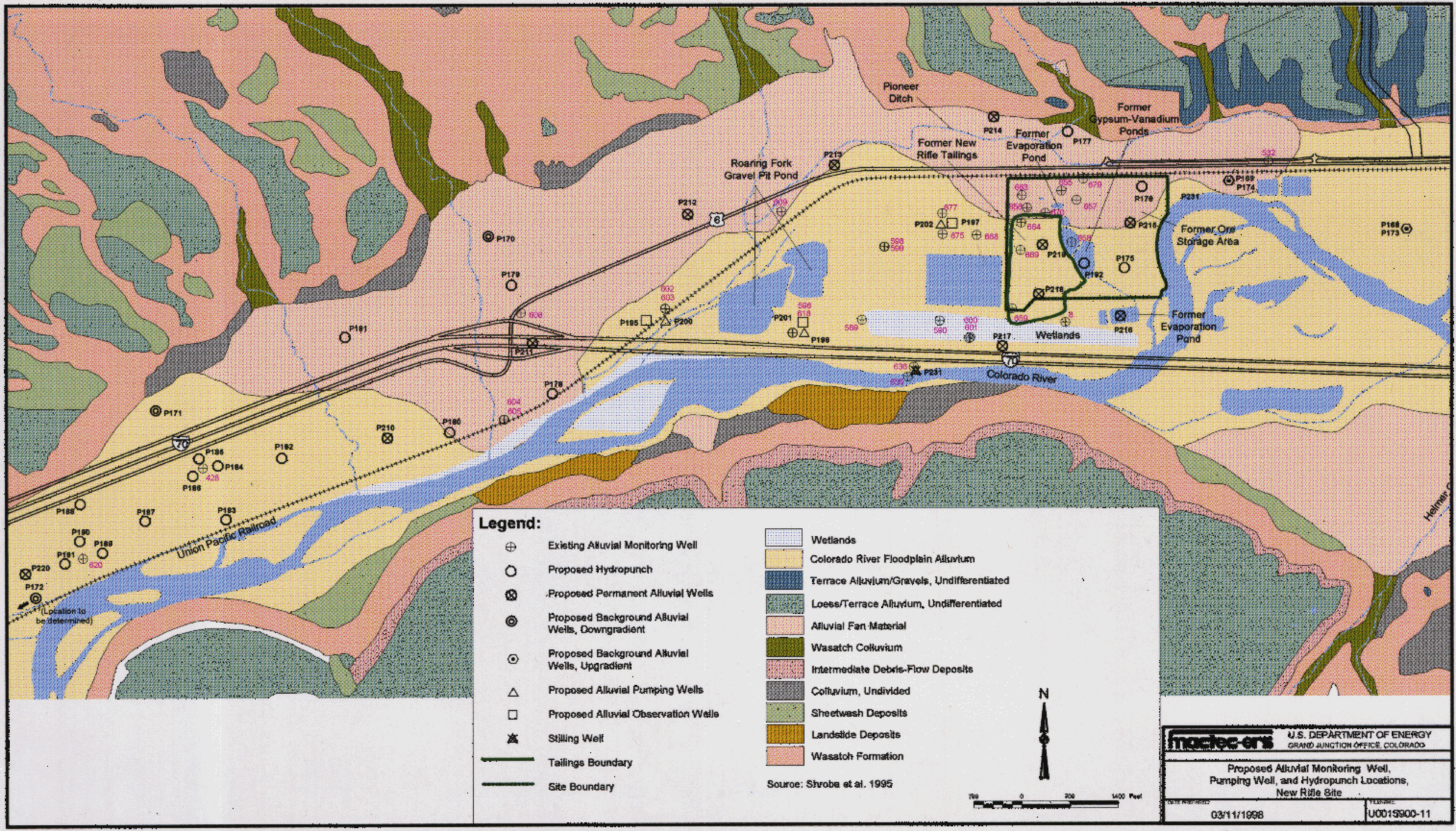


Figure 7–2. Proposed Alluvial Monitoring Well, Pumping Well, and Hydropunch Locations, New Rifle Site

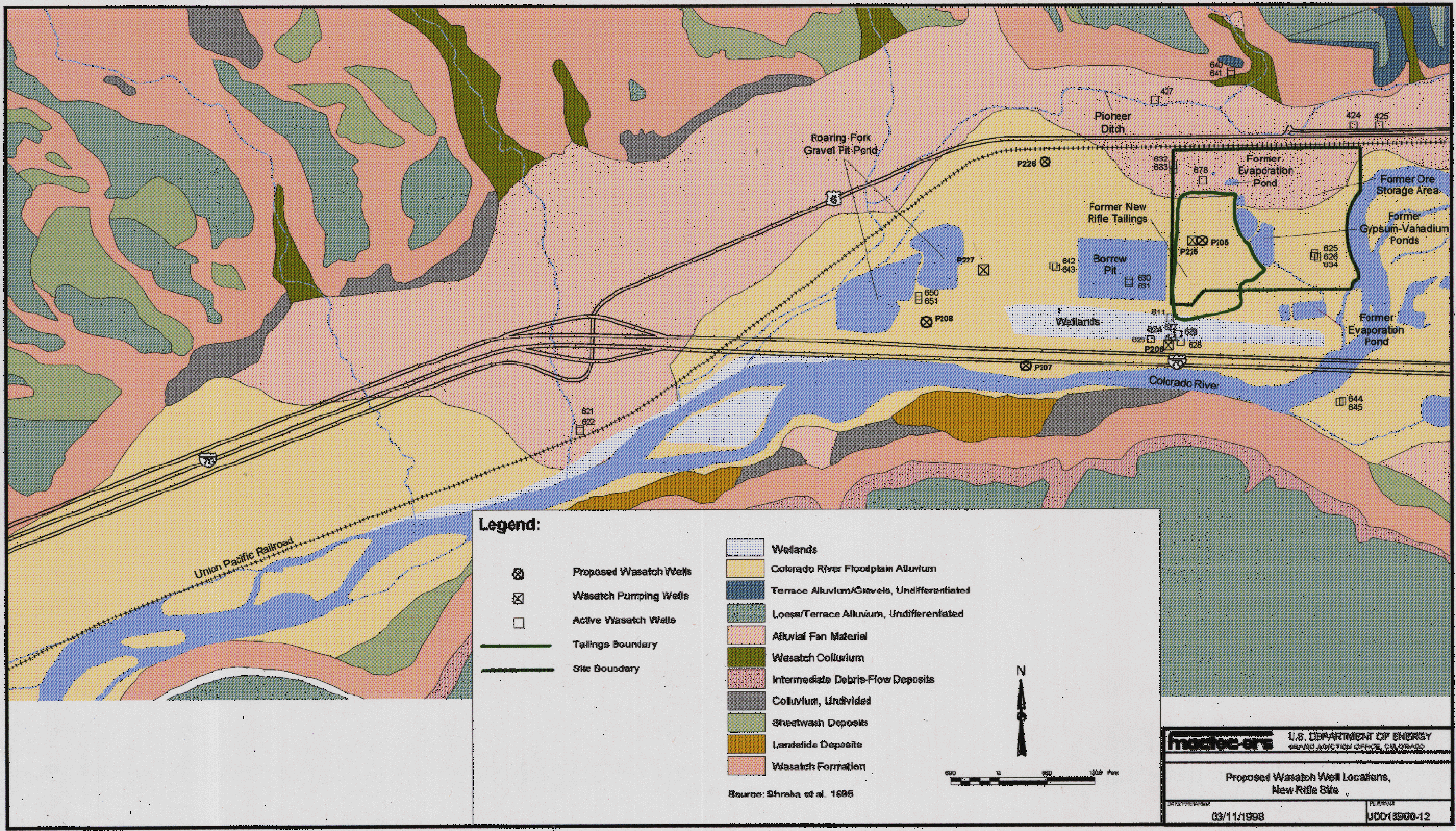


Figure 7–3. Proposed Wasatch Well Locations, New Rifle Site

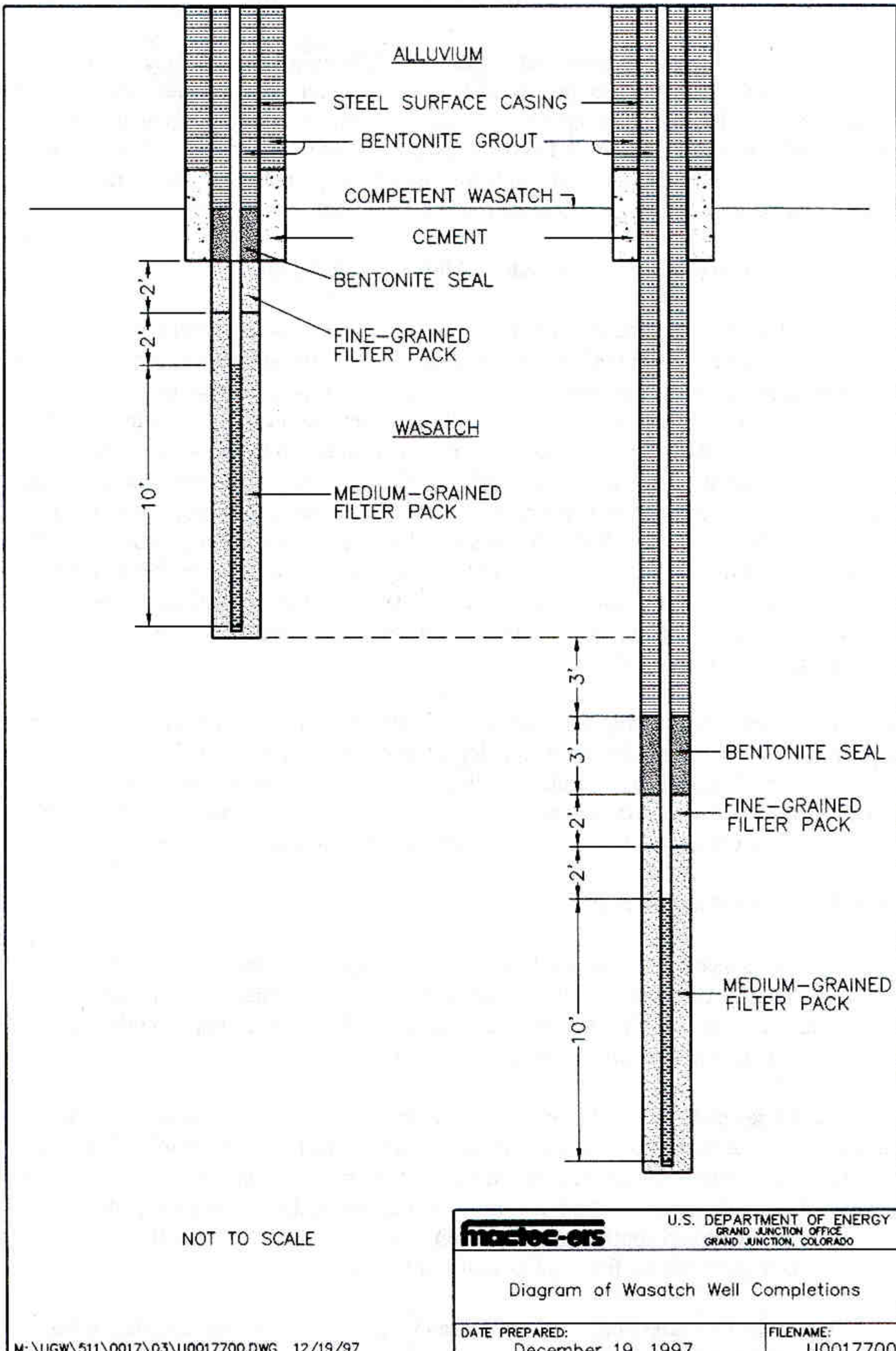


Figure 7–4. Diagram of Wasatch Well Completions

7.3 Rationale for Data Quality Objectives and Data Collection Strategies

The purpose of the site characterization at the Rifle sites is to collect the data required to (1) determine if ground-water contaminants in the alluvial aquifer will flush naturally in 100 years or less, (2) determine if the alluvial aquifer qualifies for supplemental standards on the basis of widespread ambient contamination, and (3) evaluate the incremental risk imposed by mill-related contamination in the alluvial aquifer. The following subsections summarize the rationale for the DQOs and data collection strategies presented in Tables 7S1 and 7S2.

7.3.1 Alluvial Lithology and Water Quality of the Alluvial Aquifer

Water-quality and lithologic data are currently limited for the alluvial/colluvial sediments and associated ground water at both the New and Old Rifle sites. Although numerous borings were installed at both sites, the borings were clumped into somewhat isolated areas and many of the lithologic logs for the borings are incomplete. Because of the presence of two distinct lithologies (alluvial and colluvial coarse-grained and fine-grained deposits) and the importance these lithologies have in contaminant transport, additional lithologic data for unconsolidated deposits are required at both sites. Likewise, monitoring well water quality data are limited in spatial and temporal distribution. At the Old Rifle site, no alluvial monitoring wells remain within the site boundary. At the New Rifle site, several alluvial wells are still in place, but most are in the area immediately surrounding the former tailings pile. To characterize the on-site, downgradient, and upgradient (background) contaminant distributions at the Old and New Rifle sites, additional monitoring wells will be installed.

Because of the seasonality of irrigation practices, influence from the Colorado River, and high rates of evaporation, the alluvial aquifer has a high degree of variation in water quality. A distribution of sampling locations is needed to adequately evaluate the variation in background water quality. For comparisons with site ground water to be statistically significant, background wells for each site must be completed in hydrogeologic environments that are similar to those at the site.

Alluvial Wells at the Old Rifle Site

The 10 temporary 2-inch standpipes will be placed in a rough grid across the site and used to determine the topographic surface of alluvial ground water and to characterize indicator species such as uranium, sulfate, and nitrate. Chemical Information from water samples collected from the standpipes will be used to site permanent monitoring wells.

On-site monitoring wells P655, P656, and P657 will replace abandoned wells 584, 585, and 582 so that new analyses can be directly compared to historical information. Well P654 will be located near the west end of the site on the east side of a prominent Wasatch outcrop. Water quality data from this well will be compared with data from wells located west of the outcrop to determine if the outcrop provides a barrier to contaminant migration. The 4-inch well (P663) will be located 30 ft from P655 to provide a location for a paired-well aquifer test.

Downgradient wells P652 and P653 will be installed west of the site on the west side of the Wasatch Formation outcrop that extends south toward the Colorado River. These wells will be used to test whether contamination has migrated through or around the prominent Wasatch outcrop west of the site. All wells will be drilled to the top of the Wasatch Formation. Because saturated thickness is limited to about 10 ft, on-site and downgradient wells will be screened across the entire saturated thickness of the alluvium.

Background well pairs P658/P659 and P660/P661 will be placed upgradient of the site approximately 1 mi east on the north and south sides of the railroad tracks, respectively. Each well pair will include wells screened in the upper and lower sections of the saturated alluvium/colluvium deposits. The upper deposits are expected to consist largely of fine-grained alluvium; the lower deposits typically consist of coarse-grained gravels and colluvium. Background wells will be located away from vicinity properties to minimize the potential for contamination from those sites.

Alluvial Wells at the New Rifle Site

A direct-push sampling method (Hydropunch) and field analyses as specified in Section 8.1 will be used to optimize the locations of the aquifer test wells and new monitoring wells and to define the lateral and vertical extent of COPCs. In some cases, Hydropunch borings will be completed as alluvial pumping or monitoring wells. Up to two samples will be collected to characterize the vertical profile of the ground water quality in the upper fine-grained and lower coarse-grained sections of the alluvial aquifer. The first sample will be collected just below the water table, and the second sample will be collected at the point of auger refusal or bedrock contact. Field analyses of indicator species such as U, NO_3, or SO_4 will be conducted to better define the lateral and downgradient extent of contamination. Locations were chosen in the broad alluvial valley downgradient of the site to help identify contributions of certain elements or compounds that might be entering the alluvial aquifer from drainages to the north and to define boundaries for contaminants migrating from the millsite. Hydropunch locations on the millsite were placed where monitoring wells are likely to be installed so as to provide preliminary data that will be useful for siting the wells.

A more complete ground-water monitoring well network will be established on the basis of Hydropunch data and analyses from existing wells. The five 2-inch wells proposed on and near the site will be used to characterize contamination within the original source area. The on-site wells include the wells described in Table 7**S**2 that will be sampled for subpile soil contamination during well installation. The 2-inch downgradient wells proposed for the broad floodplain west of the site will be used to help define the downgradient extent of contaminant migration and may also be suitable for monitoring future contaminant migration. The 4-inch pumping wells and 2-inch observation wells will also be included in the sampling program. Those wells will be screened across the full saturated thickness of the alluvium. Screened intervals for the on-site, downgradient, and background monitoring wells will be chosen after review of the Hydropunch data. Current data and the site conceptual model suggest that on-site contamination is present in the entire thickness of the alluvium and that off-site contaminant concentrations are greater in the lower zone of the alluvium. Screened intervals for on-site and off-site wells will be chosen to intercept the zone of highest contaminant concentrations. Upgradient of the site, if saturated thickness of the alluvium is 15 ft or greater, upgradient wells will be installed as paired completions (P168/P173, P169/P174 on Figure 7–2). Each pair will be screened in the upper and lower zone of the alluvial aquifer. If saturated thickness is less than 15 ft, upgradient wells will be installed as single completions and screened across the full saturated thickness of the alluvium. Proposed well locations are shown on Figure 7–2. The actual locations of these wells will be based on Hydropunch field data.

Water samples from all new and existing wells will be collected immediately after completion of the field program; samples will be analyzed for total dissolved solids (TDS) and the COPCs referenced and discussed in Section 8.4.

7.3.2 Contaminant Sorption in the Alluvial Aquifer

To evaluate natural flushing, interactions between ground-water contaminants and aquifer sediments need to be understood. Contaminants with high sorption potential are less likely to flush from the aquifer than are contaminants with low sorption potential. To evaluate solid phase–aqueous phase contaminant interaction, samples will be collected for analysis of the sorption characteristics of the alluvial aquifer matrix.

The most common approach to predicting chemical interactions between ground water and aquifer sediment is to employ a distribution coefficient (Kd). Kd is the ratio of contaminant concentration in sediment to contaminant concentration in water. In a natural flushing strategy, it is likely that pH and other chemical conditions will be reasonably constant for the 100-year period. Thus, changing solution chemistry will not likely have a large effect on Kd values. Most of the variation in Kd values is due to the spatial variation in concentrations of adsorbent minerals in the sediments.

Kd values can vary for the same sediment sample if different dissolved concentrations are used. For those COPCs that have maximum ground-water concentrations that exceed the MCL by an order of magnitude or more, Kd values will be determined using at least three aqueous solution concentrations. Concentrations to be used for the analysis will be determined after early data collection and analysis. Selection of either natural or synthetic ground water will also be made at that time.

Kd values will be determined by ASTM procedure D 4646–87 (ASTM 1996); these values will be determined for selected COPCs (arsenic, selenium, uranium, and vanadium).

7.3.3 Hydrologic Properties of the Alluvial Aquifer

To characterize ground-water flow and contaminant migration rates and to support ground-water modeling, the ground-water elevations and the hydraulic conductivity distribution for the alluvial aquifer are required. Ground-water elevations will be used to map water table elevations; to determine ground-water flow directions and to estimate ground-water flow rates; and to determine vertical gradients between upper and lower sediments in the alluvial aquifer, and between the alluvial aquifer and the Wasatch Formation. Seasonal fluctuations in water levels will also be used to evaluate recharge from and discharge to the Colorado River. Hydraulic conductivity and lithologic data together with hydraulic gradients will be used to estimate ground-water and contaminant migration velocities and recharge to and discharge from the Colorado River at both sites. For ground-water modeling purposes, water-level elevation and hydraulic conductivity data will be used as input parameters. Dispersivity estimates will be used for contaminant transport modeling.

New monitoring wells at the Old and New Rifle sites, both on-site and downgradient, will be installed according to the rationale described in Section 7.3.1. Drilling will continue until the auger bit contacts competent rock of the Wasatch Formation. As boreholes for the wells are drilled, 2-ft split barrel samples will be collected every 5 ft for lithologic logging. Lithologic data will be used to characterize the aquifer for modeling.

Hydraulic conductivity will be estimated using aquifer pumping tests and slug tests. Slug tests will be conducted by instantaneously removing a known volume of water and then recording the water-level recovery by means of a pressure transducer and data logger. Like the aquifer pumping tests, the slug tests will provide an estimate of hydraulic conductivity, although slug-test estimates do not characterize as much of the aquifer as do the pumping tests.

Pumping test will be performed on the wells listed in Tables 7S1 and 7S2. Existing Wasatch wells near the pumping wells will be monitored as observation wells. If no measurable drawdown is observed in observation wells, drawdown data from the pumping well will form the basis for the aquifer test analysis. Pumping tests will include 1 to 2 days of step-drawdown testing to determine suitable pumping rates for the actual aquifer test. The aquifer pumping tests will then run for 3 to 5 days on each well, during which time pressure transducers and data loggers will be used to measure drawdown in the pumping well and in the observation wells. Discharge rates will be measured with electronic flow meters that display instantaneous flow rates and cumulative volumes discharged. After pumping ceases, water-level recovery will be monitored to provide a hydraulic conductivity estimate from recovery data as well as drawdown data.

To provide data for quantifying surface-water and ground-water interactions, stilling wells will be installed at both sites to directly measure the elevation of the Colorado River. Water level elevations will be recorded using automatic data loggers referenced to a surveyed elevation at the stilling well location. Locations for the stilling wells are shown in Figures 7–1 and 7–2. River-stage data determined from the stilling wells will be used with upstream and downstream gauging-station discharge data to estimate river losses and gains to and from the alluvial aquifer.

Because hydrodynamic dispersivity can be an important parameter in characterizing contaminant transport using analytical or numerical models, a natural-gradient tracer test will be considered for the purpose of quantifying site-specific dispersivity. The decision of whether to proceed with a tracer test will be made after further evaluation of data. The decision will be based on an assessment of the importance of obtaining a field estimate of dispersivity and on the time and resources required to complete a natural-gradient tracer test.

7.3.4 Characterization of Subpile Soil

COPCs may have been sorbed in the upper few feet of the alluvial sediments (subpile soil) beneath the area of the former tailings piles and raffinate ponds. Shallow soil contamination at both sites was removed during surface remediation in the mid 1990s. Criteria for soil excavation and removal were based on a radiometric standard, however, and nonradioactive contamination may have been left in place. Evaluation of remediation strategies requires a reliable estimate of residual amounts of sorbed contaminants in the subpile soil that may behave as a continuing source of ground-water contamination. Native soils beneath the former tailings piles and mill ponds should be tested to determine if regulated COPCs are present that could provide a continuing source of ground-water contamination to the alluvial aquifer and that could contribute to human and ecological risk (Sections 4.2 and 5.0).

Samples should be selected from areas of the site that are most likely to have contaminated subpile soils. Chemical extraction and analysis methods should be capable of detecting small concentrations of contaminants (e.g., 2 micrograms per liter [µg/L] uranium in the leachate). Because most COPCs occur naturally in sediment, analytical results from the millsites must be compared to analytical results from background areas. Soil contaminants can leach into ground water by mechanisms such as (1) infiltration of precipitation, (2) a rising water table, or (3) changing chemical conditions due to land use changes (e.g., fertilizer application). A representative leaching test should examine these scenarios. The location of a contaminant source will affect the remediation strategy used at the sites and may influence values assigned to modeling parameters.

Soils directly beneath the former tailings piles and raffinate ponds at the New and Old Rifle sites will be sampled and analyzed. Most of these soil borings will be completed as monitoring wells for characterization of ground-water quality and hydrologic properties. Split-barrel samples collected from the borings will be used to determine lithology/stratigraphy and moisture content. Some samples will also be used for leaching tests. Subpile soil samples are described in Tables 7S1 and 7S2; sample locations are shown in Figures 7S1 and 7S2. No subpile soil samples will be collected in saturated alluvium.

The mobility of contaminants of interest will be determined by performing contaminant extractions using deionized water and alluvial ground water. Deionized water will serve as a surrogate rain water, characterizing contaminant leachability during precipitation infiltration. Extractions using ground water will characterize the mobility of subpile soil contamination at depths greater than the depth of the water table. All extractions will be analyzed for the COPCs listed in Table 4S2.

7.3.5 Plant Ecology and Land Use

Characterization of present and potential land use, of plant communities within the plume area and in a reference area, and of surface water in ponds fed by the plume and in a reference area are all needed to complete the screening-level risk assessment (Section 5.1). Surface-water and ground-water sampling described in Tables 7–1 and 7–2 are sufficient for the ecological investigations.

The qualitative survey (see Tables 7–1 and 7–2) will focus on plant communities likely to inhabit the site in the future. Sample sizes for tissue analyses will be calculated to satisfy a standard error of ± 20 percent of the mean at a confidence level of a = 0.10.

7.3.6 Surface Water and Sediment Contamination

Contaminated ground water from the site can potentially enter the Colorado River and nearby ponds or wetlands. Uranium concentration in a recent sample from the Roaring Fork gravel pit was 0.168 mg/L, which exceeds the uranium MCL of 0.044 mg/L. To ensure protection of human health and the environment, the potential for contamination of these surface waters should be known. Surface water samples will be collected from the locations shown on Figure 4–11 and listed in Table 4–4. These samples will be analyzed for the COPCs listed in Table 4–2.

Contaminated ground water could contaminate subaqueous sediments, which in turn could be harmful to benthic or other aquatic organisms. To ensure protection of the environment, the extent of surface-water sediment contamination will be determined. Because contaminants in surface-water sediments are assumed to be derived from contaminated ground water, river and pond sediments will be sampled at locations that show a high likelihood of ground-water discharge. Sediment sampling locations will be established during characterization of the alluvial aquifer.

7.3.7 Lithology and Water Quality of the Upper Wasatch Formation

Mudstones and shales in the Eocene Wasatch Formation have contamination in the uppermost few feet of the section. Drilling will establish the aquitard/aquifer characteristics of the upper 30 ft of the Wasatch Formation; this information is critical to the development of a ground-water flow and transport model. This interval of bedrock needs to be well defined because its characteristics influence contaminant migration, and these characteristics will play an important role in model simulations. At the Old Rifle site, it is important to define the extent of the Wasatch Formation outcrop along the western side of the site, as this feature forms a partial boundary for the alluvial flow system. Existing geologic maps place monitoring well 590 in Wasatch; however, the lithologic log describes the well as being in alluvium. If the Wasatch Formation completely intersects the Colorado River, it likely acts as a natural barrier to subsurface migration of ground water in the alluvial aquifer. Detailed geologic mapping will be conducted to determine where the Wasatch Formation is in contact with the Colorado River at the Old Rifle Site.

Ground-water contamination data for the Wasatch Formation is limited but appears to indicate that at least some contamination has invaded this unit. To define the nature and extent of contaminant distribution and migration within the Wasatch Formation, additional wells will be installed in the formation and sampled for analysis of water quality. Because data suggest that contamination is predominantly in the uppermost section of the formation, 8 of the 11 proposed Wasatch wells at the Old and New Rifle sites will be installed in the uppermost competent section. A typical diagram of the shallow and deep completions of the proposed Wasatch Formation wells is shown in Figure 7–4; proposed well locations are shown in Figures 7–1 and 7–3, specific wells planned for shallow and deep completions are listed in Tables 7–1 and 7–2.

Aquifer pumping tests in the Wasatch will be conducted in the wells described in Tables 7**S**1 and 7**S**2. Water samples from all new and existing Wasatch Formation wells will be collected immediately after completion of the field program. Samples will be analyzed for TDS and the COPCs referenced and discussed in Section 8.4.

8.0 Site Investigation Procedures

As described in Section 7.0, activities required to meet the DQOs include auger stem, diamond core, and rotary well drilling, ground-water sampling, soil leaching, determination of distribution coefficients, aquifer testing, land surveys, vegetation sampling, and chemical analysis. The following sections present the procedures that will be used to collect these data.

8.1 Ground-Water Monitoring Well, Temporary Well, and Hydropunch Installations

Monitoring wells, temporary wells, and Hydropunch sampling will be used to characterize ground-water quality and hydraulic features. Installation procedures for these activities are described in this section.

Temporary wells will be installed at the Old Rifle site to provide water quality samples and ground-water elevation data. Boreholes will be advanced to the base of the alluvial aquifer, which will be defined as auger refusal. After the borehole has been advanced to auger refusal, a temporary well casing will be installed through the hollow-stem auger. The temporary well shall have a minimum of 5 ft of screen at the bottom of the casing string. After placement of the well casing, the auger string will be removed. Sample collection and water level measurement will take place after removal of the auger. Upon completion of these activities and after the temporary well casing has been surveyed for elevation, the temporary well casing will be removed from the hole, and the hole will be abandoned as described in Section 9.0, Table 9–1. No filter pack will be placed in the temporary wells.

A truck-mounted hollow-stem auger rig will be employed at the New Rifle site to collect ground-water samples from the alluvial aquifer with a direct-push sampling device (Hydropunch). Two samples will be collected from different depths at the same location to profile the contaminant plume as a function of depth. Hydropunch sampling locations are shown in Figure 7–2. Analytical results of the direct-push ground-water sampling will be evaluated and integrated with existing data to update the site conceptual model on a day-to-day basis. The updated site conceptual model will be used to guide the locations of the next day’s sampling activities.

With the truck-mounted auger rig centered over the sample location, the auger will be advanced down through the top of the water table. The direct-push sampling device will then be inserted into the hollow-stem auger and pressed to the sampling zone of interest. A ground-water sample will be pumped to the surface or collected with a small diameter bailer and analyzed in a mobile field laboratory for uranium, sulfate, and nitrate. The second sample will be collected at the same location as the first by removing the direct-push sampler and advancing the auger to the lower half of the alluvial aquifer where coarser grained sediments are expected to be present. A ground-water sample will then be collected and analyzed in the same manner as the previous one. Samples of the auger cuttings will be collected every 5 ft and lithologic descriptions will be recorded by the site geologist.

Monitoring wells will be installed at the locations shown in Figures 7–1, 7–2, and 7–3. The wells will be completed with 2-inch or 4-inch i.d., flush-joint, threaded, polyvinyl chloride casing and screen. With the exception of background wells located upgradient (east), alluvial monitoring wells at the Old Rifle site will be screened over the entire saturated thickness. Background wells will be paired installations with a shallow well completed with a 10-ft screened interval, the top of which is located at the water table, and a deep well completed with a 10-ft screened interval, the bottom of which is at the base of the alluvial aquifer (defined as auger refusal). Screened intervals of on-site and downgradient wells at the New Rifle site will be chosen to intercept the zone of highest contamination as determined by analytical results of Hydropunch samples. Upgradient at the New Rifle site, if saturated alluvium is at least 15 ft thick, upgradient background wells will be installed as paired completions and screened across the upper and lower zone of saturation. If the alluvial aquifer is less than 15 ft thick, the wells will be installed as single completions and screened across the full saturated thickness. Wells will be completed by placing a medium-grained sand pack (likely to be 10–20 sieve size) in the annular space from the bottom of the borehole to 2 ft above the top of the well screen. A fine-grained sand pack (likely 20–40 size) will be placed to fill 2 ft of the annular space above the medium-grained sand. Sand packs shall consist of clean quartz sand. A 3-ft bentonite seal will be placed above the fine-grained sand pack. Enviroplug, Volclay, or a similar grout shall be used to fill the annular space above the bentonite seal to within 3 ft of ground surface. Concrete will be used to fill the remaining annular space to the ground surface and to install the 3-ft diameter well pad. Construction details for a 4-inch monitoring well are presented in Figure 8–1. Several Wasatch Formation well pairs will also be completed. The shallow and deep completion schematics are shown in Figure 7–4. Drilling of the Wasatch Formation will be completed by core drilling (for selected Wasatch wells described in Section 7) and rotary drilling. Rotary-drilled holes not located near an already-cored hole of a paired installation will be logged from cuttings only.

Details of the procedures that will be used for monitoring well installation are found in

- LQ–14(P), “Technical Comments on ASTM D 5092—Standard Practice for Design and Installation of Ground-Water Monitor Wells in Aquifers.”

- SL–9(P), “Technical Comments on ASTM D2113–83 (93)—Standard Practice for Diamond Core Drilling for Site Investigation.”

- GN–13(P) “Standard Practice for Equipment Decontamination.”

8.2 Soil and Rock Sample Collection for Lithologic Logging, Kd, and Subpile Soil Analysis

Soil and rock samples will be collected during the installation of monitoring wells. Samples will be collected for lithologic logging and chemical and geotechnical analysis of soils and rocks. Lithologic logging will be performed on all monitoring well boreholes to support development of the site hydrogeologic model. Chemical analysis will include analyzing for Kd and mobile fractions of COPCs. Both analyses will aid in characterizing subsurface contaminant transport. Geotechnical analysis will include a formal aquifer matrix grain-size analysis and filter-pack/well design as outlined in Driscoll (1986). The analysis will be performed as needed for wells in the

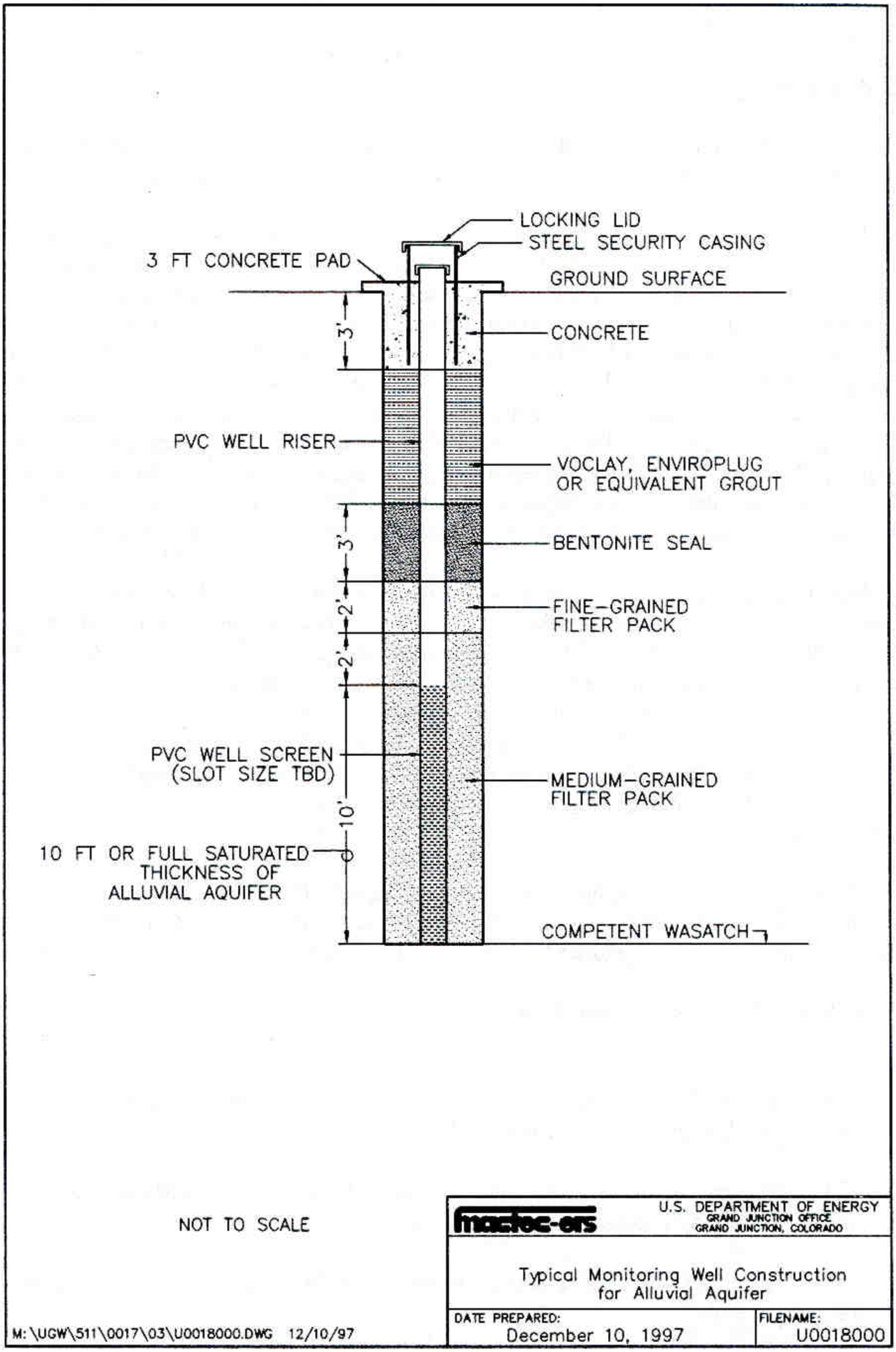


Figure 8–1. Typical Monitoring Well Construction for the Alluvial Aquifer

alluvial aquifer and wells in the Wasatch Formation. The purpose of the design is to provide for high-efficiency well installations.

Lithologic Logging

Lithologic logging of the alluvial aquifer will occur primarily during alluvial well installation through the use of a split-barrel sampler. Split-barrel samples will be collected once every 5 ft during drilling of alluvial aquifer wells. Auger cuttings will be observed and logged as necessary. Split-barrel sampling will be conducted using a truck-mounted hollow-stem auger rig centered over the sample location. The auger is advanced to the desired sampling depth. After reaching the desired sampling depth, a 3-inch o.d. by 24-inch-long split-barrel sampler is lowered to the top of the interval to be sampled. A 140-pound drop hammer, or equivalent hydraulic driver, is then used to drive the sampler the required 2 ft or until penetration is less than 6 inches per 50 blows. The barrel is then removed from the borehole, separated from the drive-rod assembly, and laid flat on an uncontaminated surface, where the head and drive shoe are removed. One-half of the split barrel is removed to expose the sample. The uppermost portion of sample in the split barrel is inspected for slough and the slough is discarded, if present. The remaining sample is considered representative. The site geologist or designee will log the material using Unified Soil Classification System terminology in Section SL–24(P) of the *Environmental Procedures Catalog* (GJO 1997).

Lithologic logging of the Wasatch Formation will occur primarily during the installation of Wasatch Formation monitoring wells through the use of continuous-core rotary drilling. Samples will be collected using a core-barrel according to procedure SL–9(P) (GJO 1997). At the Old Rifle site, two pairs of shallow- and intermediate-depth wells will be installed. The bottom of the shallow well will be 17 ft below the top of competent Wasatch Formation rock; the bottom of intermediate-depth well will be 20 ft below the bottom of the shallow well. The intermediate-depth well will be installed first using rotary coring, providing a total of 37 ft of competent Wasatch Formation core that will be logged for lithology. Figure 7–4 shows a completion diagram of a typical Wasatch aquifer monitor well.

At the New Rifle site, rotary coring will be performed on wells P205, P207, P226, and P227. P205 is an intermediate-depth well and will provide 37 ft of Wasatch core. The other wells will be shallow installations and will provide 17 ft of core from competent Wasatch Formation rock.

All sediment and soil sampling will be performed in accordance with the following procedures from the *Environmental Procedures Catalog* (GJO 1997):

- SL–6(P), "Technical Comments on ASTM D 1452–80(90)—Standard Practice for Soil Investigation and Sampling by Auger Borings."

- SL–7(P), "Technical Comments on ASTM D 1586–84(92)—Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils."

- SL–19(P), "Technical Comments on ASTM D 2488–93—Standard Practice for Description and Identification of Soils."

- SL–24(P), "Technical Comments on ASTM D 2487–93—Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)."

- GN–8(P), "Standard Practice for Sample Labeling."

- GN–9(P), "Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples."

- GN–13(P), "Standard Practice for Equipment Decontamination."

Distribution Coefficient, Kd

Samples will be collected for Kd analysis from both alluvial and Wasatch Formation wells. Alluvial wells to be sampled for Kd include the deep well at paired location P658/659, P655, P656, and P652 at the Old Rifle site, and P169, P219, P200, and P210 at the New Rifle site. A shallow and a deep sample will be collected from each of the deep wells: one at the water table and one near the base of the saturated alluvium.

Wasatch wells to be sampled for Kd include the intermediate-depth well at paired location P648/649 (Old Rifle site), the intermediate-depth well at paired location P205/225, and P227 (New Rifle site). A shallow- and intermediate-depth sample (5 to 10 ft below the top of the Wasatch and 30 to 35 ft below the top of the Wasatch) will be collected at each location.

Kd samples from the alluvial aquifer will be taken from split-barrel samples collected during the monitoring well installation (described in Section 8.1). Samples from the Wasatch Formation will be collected from core-barrel samples during the monitoring well installation (also described in Section 8.1).

Laboratory Kd analyses will be performed according to ASTM procedure D4646–87 (ASTM 1996) for all regulated and commonly retarded COPCs (arsenic, selenium, uranium, and vanadium). For analytes with ground-water concentrations exceeding MCLs by a factor of ten or greater, Kd analysis will be performed using three different aqueous concentrations to characterize the variability of Kd as a function of concentration. Concentrations to be used for the analysis will be determined after early data collection and analysis. Selection of either natural or synthetic ground water will be made at that time.

Subpile Sampling and Analysis

Alluvial soil samples will be collected during monitoring well installation to analyze for COPCs in soils located below the depth of excavation during surface remediation. This exercise will determine whether soils beneath the sites of former tailings piles, ore storage areas, and evaporation ponds are continuing to act as sources of subsurface contaminants. Two samples will be collected from each of the following monitoring well borings at the Old Rifle site: P655, P654, and P656 on site, and P661 off site. At the New Rifle site, subpile samples will be collected at P215, P216, P218, P219, and P192 (Hydropunch site). Off-site subpile (background) samples will be collected at location 168 (Figure 7–2). Samples will be collected from a 2-ft split-barrel. At each boring one sample will be collected from native soil beneath the contact with backfill (placed after the tailings remedial action) and one sample from the unsaturated zone just above the water table. This procedure will necessitate continuous sampling in the upper borehole intervals of the listed wells. Samples will be collected in clean, doubled plastic bags and marked with the site name, hole number, date, sampling interval and analysis type.

Samples will be air-dried (no oven heat). If the samples contain significant amounts of gravel larger than No. 4 sieve size (4.76 mm), they will be sieved using a No. 4 sieve to obtain grain sizes suitable for laboratory analysis. Because soil contaminants are likely to be in the fine-grained material, sieving may bias analytical results toward higher solid-phase concentrations than are actually present. Weight fractions of sieved samples will be recorded.

For each sample used in the extractions described below, a petrographic thin section will be prepared. Thin sections will be used to identify mineral phases, and because some of the mineral phases (such as calcite) are water soluble, oil will be used for cutting and polishing.

The mobility of contaminants of interest will be determined by performing contaminant extractions using deionized water and alluvial ground water. Deionized water will serve as a surrogate rain water, characterizing contaminant leachability during precipitation infiltration. Extractions using ground water will characterize the mobility of subpile soil contaminants below the water table. Contaminant extractions will be performed sequentially, first with deionized water, then with ground water. The same sample will be used in each extraction to preclude problems arising from sample variability. The extraction using ground water will be harsher than the deionized extraction, and will therefore be capable of solubilizing additional contamination. After completing the extractions, the solid phase residue will be completely digested and analyzed.

The specific steps in the extraction procedure are as follows:

- Place 2 g of soil (accurately weighed) in a 100-milliliter (mL) centrifuge tube (or divide between two 50-mL tubes).

- Add 100 mL of deionized water and shake the contents on an end-over-end shaker for 4 hours.

- Analyze a split of deionized water for COPCs (Table 4–2).

- Centrifuge contents to remove particles less than 2 micrometers (µm). Decant supernatant into a 200-mL volumetric flask.

- Add additional deionized water (about 100 mL) to the sample residue. Shake contents for 15 minutes, centrifuge, and decant into the 200-mL flask. This step will remove most of the residual constituents from the sample.

- Fill the 200-mL flask to volume with deionized water and filter through a 0.2 µm filter. Measure pH, alkalinity, and Eh. Preserve the remaining water and send it to the analytical laboratory for analyses.

- Add approximately 100 mL of site ground water to the residue in the 100-mL tube and shake for 4 hours.

- Analyze a split of ground water for the COPCs listed in Table 4–2.

- Centrifuge contents to remove particles less than 2 µm in diameter. Decant supernatant into a second 200-mL volumetric flask.

- Add additional site ground water (about 100 mL). Shake contents for 15 minutes, centrifuge, and decant into the second 200-mL flask.

- Fill the 200-mL flask to volume with site ground water and filter through a 0.2 µm filter. Measure pH, alkalinity, and Eh. Preserve the remaining water and send it to the analytical laboratory for analyses.

- Dry, grind, digest completely, and analyze the residue.

- Analyze all samples for the COPCs listed in Table 4–2. Analyze background samples for the New Rifle site COPCs (Table 4–2, column 2); also analyze the site ground-water sample for these constituents.

- Calculate the amount of each constituent removed during each step. Calculate the total amount of each constituent.

8.3 Ground-Water Sampling

Each new monitor well will be undisturbed for at least 40 hours after final completion before it is developed. Development will be performed according to the Drilling Statement of Work. Ground-water sampling will be performed in accordance with the *Addendum to the Sampling and Analysis Plan for the UMTRA Ground Water Project* (DOE 1996a) and the *Environmental Procedures Catalog* (GJO 1997). Ground-water samples will be collected from the new monitor well network and from all existing wells and submitted to the Grand Junction Office (GJO) Analytical Laboratory for analyses. Samples will be collected once during high river flow (May–July) and once during low flow (October–February).

The following procedures from the *Environmental Procedures Catalog* (GJO 1997) will be used for ground-water sampling:

- GN–8(P), “Standard Practice for Sample Labeling.”

- GN–9(P), “Standard Practice for Chain-of-Sample-Custody and Physical Security of Samples.”

- GN–13(P), “Standard Practice for Equipment Decontamination.”

- LQ–2(T), “Standard Test Method for the Measurement of Water Levels in Ground-Water Monitor Wells.”

- LQ–3(P), "Standard Practice for Purging Monitor Wells."
- LQ–4(T), "Standard Test Method for the Field Measurement of pH."
- LQ–5(T), "Standard Test Method for the Field Measurement of Specific Conductance."
- LQ–6(T), "Standard Test Method for the Field Measurement of the Oxidation-Reduction Potential (Eh)."
- LQ–7(T), "Standard Test Method for the Field Measurement of Alkalinity."
- LQ–8(T), "Standard Test Method for the Field Measurement of Temperature."
- LQ–9(T), "Standard Test Method for the Field Measurement of Dissolved Oxygen."
- LQ–10(T), "Standard Test Method for Turbidity in Water."
- LQ–11(P), "Standard Practice for Sampling Liquids."
- LQ–12(P), "Standard Practice for the Collection, Filtration, and Preservation of Liquid Samples."

8.4 GJO Analytical Laboratory Sample Analyses

Ground-water samples will be submitted to the GJO Analytical Laboratory. All procedures will be checked for accuracy through internal laboratory quality-control checks (e.g., analysis of blind duplicates, splits, and known standards). Table 8–1 lists the analytical methods to be used for analysis of ground-water samples. Sample preservation will consist of storing the samples in an ice chest with Blue Ice (or equivalent) to cool samples during field sampling, packaging, and shipping. Ground-water samples will be analyzed for TDS and the COPCs listed in Table 4–2. Analysis will include U-234 and U-238 activity concentrations (pCi/L) and mass (mg/L) for the first round of sampling. These analyses will be used to evaluate secular equilibrium. Sample handling, preparation, and analyses are described in the references shown in Table 8–1.

Table 8–1. GJO Analytical Laboratory Sample Requirements

Measurement Parameter	Analyte	Sample Container	Analytical Instrument/Method	Detection Limit
Ground Water	Total uranium	2 each 120 mL	ICP/MS EPA 6020	1.0 µg/L
	Other Inorganics	See Supplemental Water Sampling and Analysis Plan for all UMTRA Sites (DOE 1996f) and *Addendum to the Sampling and Analysis Plan for the UMTRA Ground Water Project* (DOE 1996a).		

8.5 Hydrologic Tests

As described in Section 7.0, several types of hydrologic measurements are required to meet the DQOs. Procedures for collecting these data are presented in this section.

8.5.1 Measurements of Water Levels Using a Data Logger

During the water-level monitoring period, an absolute-pressure transducer will be set up to monitor changes in atmospheric pressure. Pressure transducers from In-situ, Inc. (or equivalent) will be used to measure water levels. The transducers will be positioned 5 ft above the bottom of the wells. Transducer setup parameters, installation depth, model, and serial number will be recorded in a field log book before the start of baseline data collection.

Water-level and barometric-pressure data will be recorded at 1-hour intervals by using the In-situ, Inc. HERMIT model data logger, or the In-situ, Inc. SENTINEL model, or the Geoguard Tuber Model. The clocks of the data loggers will be synchronized, and each logger will be programmed to display and record data in the “depth to water” mode relative to the top of the casing. To verify the accuracy of the transducers during the monitoring period, the “depth to water” displayed on the logger will be compared with manual readings taken with a water-level sounder. User manuals from In-situ, Inc. or Geoguard will be followed for logger setup, calibration, and programming.

After completion of data collection, water levels will be downloaded to a laptop computer. Files will be named and stored according to conventions described in the *Data Logger Data Management Plan* (DOE 1996c).

Manual water-level measurements will be performed according to the *Environmental Procedures Catalog* (GJO 1997) procedure LQ–2(T), “Standard Practice for the Measurement of Water Levels in Ground Water Monitoring Wells.”

8.5.2 Step-Drawdown Aquifer Test

Field Procedure: The step-drawdown test will be performed by pumping the well at a low constant discharge until drawdown within the well stabilizes. The likely initial extraction rate for a well completed in the alluvial aquifer will be 1–2 gallons per minute (gpm). The pumping rate will be increased to a higher constant-discharge rate, and the ground water will be pumped until drawdown in the well stabilizes. The process will be repeated until the maximum sustainable yield for the well has been determined.

Flow will be measured by using an instantaneous flow meter such as a Great Plains Industrial flow meter or equivalent. Flow rates will be logged on a data form or in a field logbook. After downloading baseline water-level data, the data loggers will be reprogrammed for a logarithmic sampling schedule. Water-level data will be continuously recorded by a data logger as the test proceeds. Proper operation of the transducer and data logger will be confirmed by taking manual water-level measurements at 1-hour intervals and by comparing the results with data logger output. Recorded data will be transferred to a laptop computer by using hardware interfaces and software and will be converted to working files by using the appropriate software.

Data Analysis: Various methods are available to analyze step-drawdown test results for an unconfined aquifer (alluvial aquifer). The step-drawdown data will be analyzed by the Hantush-Bierschenk method (Kruseman and deRidder 1990), the Rorabaugh straight-line method (Kruseman and deRidder 1990), or Sheanhan’s curve-fitting method (Kruseman and deRidder 1990), or two or all three methods. These methods also apply to analysis of step-drawdown data for a confined or semiconfined aquifer (bedrock aquifer). Step-drawdown data from testing the bedrock aquifer can also be analyzed by the Eden-Hazel method (Kruseman and deRidder 1990).

8.5.3 Aquifer Tests

Baseline Data: Baseline water-level data will be collected from selected monitoring wells before aquifer testing. The baseline water-level data will be used to determine if rising or falling water levels exist before the start of the aquifer test(s). Baseline water levels will be collected at half-hour intervals for at least 5 days before the start of the test.

Procedure: The aquifer tests will be performed by pumping the well at a constant discharge for at least 48 hours. As reported by Todd (1980), the minimum pumping time required to attain a delayed-yield response in an unconfined aquifer is approximately 30 hours. The pumping rate required to propagate a drawdown cone through the alluvial ground water will be determined from the results of the step-drawdown tests. Whether a delayed-yield response is expected from the Wasatch aquifer has not yet been determined. Consequently, the Wasatch aquifer pumping test will be run for at least 48 hours as well. Recovery of ground-water levels (residual drawdown) will be measured until 95 percent of the maximum drawdown has dissipated.

Flow will be measured by using an instantaneous flow meter such as a Great Plains Industrial flow meter or equivalent. Flow rates will be logged on a data form or in a logbook. After baseline water-level data are downloaded, data loggers at the wells to be tested will be reprogrammed for a logarithmic sampling schedule. Water levels in the observation wells will be continuously recorded by a data logger as the test proceeds. Proper operation of the transducer and data logger will be confirmed by taking manual water-level measurements at 1-hour intervals and comparing the results with data logger output. Recorded data will be transferred to a laptop computer by using hardware interfaces and software and will be converted to working files by using the appropriate software.

Slug tests will be performed by instantaneously removing a known volume of water from the well and logging the well response using an electronic pressure transducer/data-logger combination.

Data Analysis: For the aquifer tests in the alluvial aquifer, assuming unconfined and unsteady conditions, Neuman’s or Moench’s curve-fitting methods (Kruseman and deRidder 1990; Moench 1995), or both, will be used to reduce data. The same methods will be used to analyze data from the Wasatch Formation tests if the Wasatch aquifer is found to be unconfined. If the Wasatch Formation is best regarded as a confined aquifer, a partial-penetration version of the Theis model will be used (Kruseman and deRidder 1990).

For slug tests, the Bouwer and Rice method of analysis will be used (Kruseman and deRidder 1990).

Aquifer tests and data analysis will be conducted in general accordance with the following GJO and ASTM procedures:

- LQ–22(T), “Standard Test Method for Conducting Slug Tests in Aquifers.”

- LQ–15(P), “Standard Practice for Analyzing Slug Test Data for Estimating the Hydraulic Conductivity of Saturated Porous Media.”

- D4043–91, “Standard Guide for the Selection of Aquifer-Test Method in Determining of Hydraulic Properties by Well Techniques.”

- D4050–91, “Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems.”

- D5472–93, “Standard Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well.”

- D5473–93, “Test Method (Analytical Procedure) for Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer.”

8.6 Land Surveys

At the conclusion of the drilling, physical coordinates and elevations for each monitor well, soil boring, and physical features will be determined by a registered land surveyor. The survey team will follow standard contractor survey practices and procedures.

8.7 Vegetation Sampling and Analysis

Species composition and relative abundance in plant communities will be characterized using a modified relevé method (Bonham 1989). This method involves subjectively selecting representative stands of each vegetation type, walking through the stands and compiling a list of all species noted, and assigning species to cover classes. Cover will not be measured precisely. A species will be placed in one of six cover classes (< 1 percent, 1–5 percent, 6–25 percent, 26–50 percent, 51–75 percent, and 75–100 percent).

Samples of species rooting into ground water will be analyzed for ground-water COPCs (Table 5–1). Samples will be collected from areas underlain by contaminated ground water as well as in reference areas. Analytical methods may include those of the Association of Official Analytical Chemists, EPA SW–846, EPA Contract Laboratory Program Special Analytical Services, or combinations of these methods. Acceptance criteria for laboratory analysis, including calibration of laboratory equipment and internal laboratory quality control (QC) checks (e.g. reagent blanks, duplicates, matrix spikes) are specified by the analytical method. Laboratory documentation will be maintained for all analytical results. Approximately 20 samples will be analyzed.

8.8 Quality Assurance and Quality Control

The objective of quality-assurance and QC measures is to provide systematic control of all tasks so as to maximize accuracy, precision, comparability, and completeness. Sections 8.8.1–8.8.4 describe the measures that will provide quality assurance and QC for sampling and analysis.

8.8.1 Sampling Procedures

Basic sampling procedures are presented in the *Environmental Procedures Catalog* (GJO 1997). Deviations from these procedures will be noted in a Field Variance Log with an explanation and a description of its possible effect on data quality.

8.8.2 Sample Control

To maintain evidence of authenticity, the samples collected must be properly identified and easily distinguished from other samples. Samples collected at the Rifle sites will be identified by a label attached to the sample container specifying the sample identification number, location, date collected, time collected, and the sampler’s name or initials.

Soil and ground-water samples for laboratory analyses will be kept under custody from the time of collection to the time of analysis. Chain-of-custody forms will be used to list all sample transfers to show that the sample was in constant custody between collection and analysis.

While the samples are in shipment to the GJO Analytical Laboratory, custody seals will be placed over the cooler opening to ensure that the integrity of the samples has not been compromised. The receiving laboratory must examine the seals on arrival and document that the seals are intact. Upon opening the container, the receiving laboratory will note the condition of the sample containers (e.g., broken or leaking bottles).

All sample shipments will be made in compliance with Department of Transportation (DOT) regulations (49 CFR 171–179) governing shipment of hazardous materials and substances. These regulations govern the packaging, documentation, and shipping of hazardous material, substances, and waste. Special care will be taken to ensure the integrity of the sample through proper packaging and shipping.

To determine the proper identification of a hazardous sample, field personnel will review field measurement data and field notes for relevant information concerning the sample material in a container. This information will include organic vapors detected, pH, explosive potential, and any other information that might be useful in classifying the sample for shipment. If a sample is known or suspected to contain a specific hazardous material, the sampler will note its presence on the sample label. This information is important to the receiving laboratory to determine the proper handling of the sample before analysis.

8.8.3 Laboratory Quality Control

Laboratory QC will follow the specifications in relevant EPA (SW–846) or the *Handbook of Analytical and Sample-Preparation Procedures*, Volumes I, II, III, and IV (*WASTREN–GJ* undated). Quality control will include analysis of blanks, duplicates, spikes, and check samples.

8.8.4 Field Quality Control

Approximately 10 percent of the samples collected and analyzed will be field QC samples. QC samples will include equipment blanks, trip blanks, check samples, and duplicates. These samples will be analyzed for the same analytes as other samples.

9.0 Environmental Compliance Requirements/Actions

The issues and actions described below are based on a review of the requirements under Federal, State, and local regulations and DOE orders.

9.1 Environmental Assessment

Actions proposed in this work plan will be assessed under DOE's National Environmental Policy Act (NEPA) regulations, 10 CFR Part 1021. On the basis of initial review, it appears that the proposed work will meet the requirements for categorical exclusion. Therefore, an environmental checklist will be prepared and a recommendation for categorical exclusion (CX) will be transmitted to DOE-Albuquerque for approval. Permits and authorizations are required to be submitted and approved before CX approval by the DOE-Albuquerque NEPA compliance officer.

9.2 Well Installation/Water Use

The State of Colorado regulates wells installed for site characterization under the UMTRA Ground Water Project. Notices of Intent will be prepared and submitted to the Colorado Division of Water Resources (State Engineer) before the start of field work. Permits will be obtained for all new wells required for long-term monitoring or other water uses. Access agreements with landowners will be in place before field work begins on private land outside the Rifle UMTRA site boundaries. Permit and agreement processes will begin as soon as the well locations are chosen.

9.3 Cultural Resources Issues

Cultural resources will be protected in accordance with Federal and State regulations. If work is planned in undisturbed areas, access to conduct the survey and the need for a cultural resources survey will be discussed with the landowner. If the landowner consents to the survey, it will be subcontracted to a qualified survey company permitted to perform work in the state of Colorado. Results will be reported to the Colorado State Historic Preservation Officer. Cultural resources surveys are not planned for any areas, or access to areas, that have been previously disturbed or surveyed.

9.4 Wetlands/Floodplain

A mitigation wetland is located between the south boundary of the New Rifle site and the Colorado River (Figure 7–2). If the work is outside the scope of work authorized in the wetland area, the U.S. Army Corps of Engineers will be consulted. Collecting samples of soil, water, and biota is not considered intrusive if samples are collected on foot. If necessary, a floodplain/wetlands assessment will be conducted in accordance with 10 CFR Part 1022.

Many of the proposed well locations are on the 100-year or 500-year floodplains of the Colorado River. Disturbances to the floodplain surface resulting from well installation would be mitigated by reseeding.

9.5 Threatened and Endangered Species

T&E species are discussed in the Rifle Final EIS (DOE 1990). Several plant and animal T&E species have been identified near the site. Plant species include the wetherill milkvetch. Animal species include the bald eagle, which winters along the river; the southwestern willow flycatcher, which may inhabit willow patches along the river; and the Colorado squawfish, which may inhabit the side channels of the Colorado River near the sites. Once well sites are chosen, studies and documentation will be reviewed to ensure protection of T&E species. If wells are located in areas that may affect T&E species, the landowner and U.S. Fish and Wildlife Service will be consulted.

9.6 Off-Road Activities

Existing roads and trails (including previous routes used to access wells) will be used wherever possible. Any off-road activities, routes, and access will be cleared through the MACTEC–ERS compliance specialist and will be conducted in a manner that minimizes adverse effects on soils, vegetation, and other natural resources. During inclement weather, the MACTEC–ERS field supervisor will be responsible for determining the conditions under which off-road travel will be permitted. Any adverse effects created as a result of off-road travel, including rutting, will be mitigated. Mitigation will be coordinated with the landowner and may include recontouring and reseeding.

9.7 Transportation of Samples and Reagents

Transportation of samples and hazardous materials (e.g., analytical reagents and sample preservatives) are addressed in Section 7.0 and Appendix C of the *Management Plan for Field-Generated Investigation-Derived Waste,* (IDW Plan) (DOE 1997a). Transportation of all hazardous materials will be managed in accordance with DOT regulations and any applicable EPA, State, local, or facility-specific protocols.

9.8 Waste Management

The strategy for management of investigation-derived waste (IDW) generated from well drilling, development, and monitoring is tiered to the IDW Plan. Proper implementation of this strategy will ensure that IDW is managed in a manner that is protective of human health and the environment and is in accordance with Federal and State regulations.

DOE intends to dispose of contaminated IDW that cannot be disposed of on-site (e. g., disposable sampling equipment, miscellaneous debris, and personal protective equipment (PPE) contaminated with residual radioactive material [RRM]) at the Cheney Repository. Prior approvals from the DOE-Albuquerque Office, the State of Colorado, and the Nuclear Regulatory Commission shall be obtained for the site before initiating off-site shipments to the repository.

9.8.1 Regulatory Requirements

IDW generated during this site investigation will be managed in accordance with all applicable Federal and State requirements. A summary of the key regulations applicable to the management and disposal of these wastes is presented in the IDW Plan and should be reviewed as a part of the

IDW disposition process. Brief descriptions of regulations pertaining to this site are provided in the following paragraphs.

The UMTRA remediation standard for ground water is the value below which there are no regulatory requirements for management of the radioactive content in liquid IDW, including sample residue and analytical process wastes associated with the UMTRA Ground Water Project. Liquid IDW in the form of sample residue and analytical process wastes, which meet the UMTRA remediation standard of less than 30 pCi/L U-234 and U-238 (0.044 mg/L, assuming secular equilibrium), and are not otherwise regulated (or meet the criteria of Resource and Conservation Recovery Act [RCRA]-exempt waste) may be solidified, managed as solid waste, and disposed of at a RCRA Subtitle D landfill (i.e., municipal landfill). The UMTRA surface remediation standard of 5 pCi/g Ra-226 and Ra-228 is applicable to surface-contaminated material. Those solids suspected of being contaminated in bulk will be tested for radioactivity in accordance with the IDW Plan.

The UMTRA Ground Water Project is not regulated under RCRA. However, if small quantities (<100 kg per month) of waste materials are produced and are regulated under RCRA, the waste will be managed in compliance with 40 CFR 261.5, “Special Requirements for Hazardous Waste Generated by Conditionally Exempt Small Quantity Generators,” and in accordance with applicable State regulations. Under RCRA, these small-quantity wastes are not subject to regulation under 40 CFR Parts 124, 262 through 266, 268, and 270, and the notification requirements of Section 3010 of RCRA.

EPA developed a guidance document (EPA 1992) to ensure that management of IDW generated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) field investigations provides protection of human health and the environment and complies with applicable regulatory requirements. Because the goals of UMTRA IDW management are consistent with this CERCLA guidance, some of the options may be applicable.

EPA’s guidance describes the allowable disposal of IDW within an area of contamination (AOC) as follows: “Storing IDW in a container within the AOC and then returning it to its source is allowable without meeting the specified Land Disposal Restrictions treatment standards. ...Therefore, returning IDW that has been stored in containers within the AOC to its source does not constitute land disposal as long as containers are not managed in such a manner as to constitute a RCRA storage unit as defined in 40 CFR 260.10. In addition, sampling and direct replacement of waste within an AOC do not constitute land disposal.” Although RCRA does not apply to UMTRA IDW, this management scenario is a viable option for the UMTRA Ground Water Project as long as best professional judgement and best available information indicate that the disposal of IDW purge water around the area of the well will not present a risk to human health or the environment. Criteria to determine risk to human health and the environment for the surface dispersion of well water are defined in detail in the IDW Plan.

The CDPHE Water Quality Control Commission has adopted “Regulations for State Discharge Permit System,” 6.1.0 (5 CCR 1002–2). These regulations implement the Colorado Water Quality Control Act as amended, specifically Sections 25–8–501 through 506 of the *Colorado Revised Statutes* (CRS). Section 25–8–506 of the 1995 CRS states that “No permit for the discharge, deposit, or disposal of nuclear or radioactive waste underground shall be required in any case where ground-water quality regulation is conducted under article 11 of this title, or under the Uranium Mill Tailings Radiation Control Act of 1978 (P.L. 95-604) or a successor statute,...).” This statute is applicable to the discharge of aquifer pumping test water to trenches located within the area of contamination, as described in Section 9.8.2 below.

9.8.2 On-Site Disposal of IDW

In general, and to the extent possible, RRM IDW will be disposed of on site, either around the well itself or in trenches located in areas of ground-water contamination. This IDW includes well development water, well purge water, aquifer pumping test water, equipment decontamination water, borehole drill cuttings and soils, and excess field samples. As stated in the IDW Plan, water, soil, and excess samples from drilling, developing, and routine monitoring of wells outside of the area of contamination (outside of the former tailings footprint) will be dispersed on the ground in the area around the well. All pumping test waters will be disposed of in trenches either near the wells or in areas of known ground-water contamination. Solid IDW that is not contaminated with RRM will be disposed of at a municipal landfill.

In the unlikely event that organic contamination is suspected, all ground water and soil should be disposed of at least 12 inches below ground surface in the area around the well. Wells suspected of organic contamination should not be used for aquifer pumping tests.

Well Installation and Development IDW

Because the aquifer pumping tests will occur at a significantly later date than the well installation and development, it is necessary to separate the management of pumping test water from other IDW waters. Management of IDW water, within the former tailings footprint, other than that generated by pumping tests is proposed as follows:

- With the exception of equipment decontamination water, liquid IDW generated during well installation, development, and monitoring shall be dispersed on the surface of the ground in accordance with the criteria specified in the IDW Plan.

- Drill cuttings and borehole soil will be placed on plastic sheets and scanned with hand-held scintillometers to determine if elevated gamma activity is present. If gamma activity is within the range of background, the soils and cuttings will be spread on the ground around the well. If gamma activity exceeds background, the drill cuttings shall be disposed of at least 12 inches beneath the surface of the ground. Equipment decontamination water will be disposed of the same as the drill cuttings. This procedure will ensure that contaminated sediments in the rinse water or drill cuttings will be placed beneath the surface of the ground at a depth consistent with the following surface remediation standards defined in 40 CFR Part 192.12:

  “(a) The concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than—

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and
(2) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface."

This procedure will also minimize the potential for exposure to humans and the environment.

Aquifer Pumping Test Water

Solid and liquid IDW generated from aquifer pumping tests and monitoring in contaminated areas will be disposed of in trenches excavated on site in the vicinity of the well. Size and depth of the trenches may vary depending on logistics and depth of the backfill material. The depth of the on-site IDW pit will not extend into the ground water.

To avoid contaminating the backfill placed after surface remediation, the backfill will be removed and stored for later use. Water discharged to the trench will be maintained at a level below the depth of the backfill; therefore, no significant quantities of contaminants will be added to the clean backfill material. Pumping tests will be staggered over a period of time to allow the water to return to the aquifer and to prevent overfilling the trenches. To avoid direct contact between the aquifer pumping-test water and the backfill material, the trenches will be refilled with the clean backfill only after the water has percolated back into the aquifer. To minimize the potential for exposure, the trenches will be backfilled and the area reclaimed as quickly as possible after the tests are completed and the water has re-entered the aquifer. The areas around the trenches will be fenced and will have controlled access.

Other IDW

All equipment and PPE decontamination water will be collected and emptied into the trench. Soil samples collected for field analyses (if any) will be placed in the trench. Sample containers for the field analysis will be rinsed with deionized water and scanned for radioactive contamination. Decontaminated containers will be disposed of as solid waste at a municipal landfill. In the unlikely event that the containers cannot be decontaminated, they will be managed as RRM and disposed of at Cheney Repository.

Approval for the Use of Trenches

The use of IDW trenches for disposing of the significant volume of water generated during aquifer pumping tests requires the approval of CDPHE. This disposal scenario and other options have been presented to the State. Concurrence will be obtained before trenches are used at the Rifle sites.

9.8.3 Off-Site Disposal of IDW

The following IDW materials will be disposed of off site: excess sample material associated with off-site analyses, field test-kit waste, field calibration standards, and disposable PPE. Excess liquid sample material and any analytical laboratory process waste generated as a result of off-site sample analyses will be managed and disposed of by the off-site laboratory. Soil samples analyzed by the GJO Analytical Laboratory will be stored at the GJO until the established retention period expires.

At that time, the samples will be disposed of at the municipal landfill or at Cheney Repository, as appropriate.

Unless field-generated wastes (e.g., field calibration standards, used portions of field test kits, and sample residues) are determined to be radiologically contaminated, they will be disposed of at a municipal landfill at the conclusion of the site investigation. All field-generated wastes determined to be contaminated with radioactivity will be managed as RRM and disposed of at Cheney Repository.

Disposable PPE will be decontaminated in the field and disposed of at the municipal landfill. In the event that PPE cannot be decontaminated, it will be managed as RRM and disposed of at Cheney Repository.

IDW that is expected to be generated during the site investigation at the Rifle site, the estimated volumes, and the approach for waste management and disposal are described in Table 9–1.

Table 9–1. Summary of IDW Types, Volumes, and Disposal Methods

Description	Volume Expected	Disposition
Drill cuttings from permanent wells	762 ft^3 (103 55-gallon drums, about 2.3 drums per well × 45 wells)	When drilling into the former footprint of tailings, drill cuttings will be scanned to ensure they do not exceed surface remediation criteria for radioactive contaminants. If they do not, the cuttings and borings will be dispersed on the ground. Material that exceeds surface criteria will be buried at least 1 ft below the surface of the ground and covered with the clean soil removed from the hole. For wells outside of the former tailings footprint, cuttings will be dispersed on the surface of the ground.
Drill cuttings resulting from Hydropunch holes, temporary wells, and test borings that are to be refilled	510 ft^3 (69 55-gallon drums, about 2.3 drums per well × 31 wells)	Where possible, drill cuttings will be placed in the open borehole to within 5 ft of the ground surface or to the static water level. The remainder of the borehole will be grouted to the ground surface. Excess drill cuttings will be disposed of as described in Section 9.8.2.
Well development water	36,800 gallons (800 gallons per well × 46 wells [excluding Hydropunch wells, stilling wells, and temporary wells])	On-site surface dispersion; see *Management Plan for Field-Generated Investigation Derived Waste* (DOE 1997a).
Pumping-test water	8 wells totaling about 112,000 gallons	Discharge on site in trenches and allow to recharge to the aquifer.
Equipment/personnel rinse water	5,160 gallons (10 gallons per well for equipment; 50 gallons per well for drill rig after drilling x 86 wells)	Background wells: on-site surface dispersion. Wells within the former tailings footprint: place in trench (>12 inches deep) in area of well.
Well purge water	5,500 gallons (100 gallons per well x 55 wells)	On-site surface dispersion; see *Management Plan for Field-Generated Investigation Derived Waste* (DOE 1997a).
Excess sample material—ground water	220 liters (1 liter per well x 220 samples)	Disposed of by the receiving GJO Analytical Laboratory.
Excess sample material—soils	40 kilograms (88 pounds) (200 samples x 200 grams/sample)	Disposed of by the receiving GJO Analytical Laboratory.
Empty sample bottles	About 400 empty and rinsed bottles	Dispose of as general refuse in local landfill.

Table 9–1 (continued).Summary of IDW Types, Volumes, and Disposal Methods

Description	Volume Expected	Disposition
Field test kit wastes	5–10 gallons	Based on 40 CFR 261.5, these wastes will be disposed of at a RCRA Subtitle D facility (municipal landfill) or at the Cheney Disposal Cell if they meet the definition of RRM.
PPE	Well drilling and development: 74 ft^3 (10 drums) uncontaminated PPE	Dispose of as general refuse in a municipal landfill.
	Initial well sampling: 30 ft^3 (4 drums) uncontaminated PPE	Dispose of as general refuse in a municipal landfill.
	Contaminated PPE and bottles: 7.4 ft^3 (1 drum)	Dispose of at Cheney Disposal Cell.

9.8.4 Management of Spills

Because the only significant equipment used for characterization are trucks and drill rigs, any spills would most likely be petroleum products. Actions that prevent spills and overfills will be used when refueling drill rig generators or trucks in the field.

The volume available in the fuel tank should be greater than the volume of fuel in the transfer container, and close attention should be given to all refueling operations. Equipment operators should watch constantly to prevent spills and overfills.

In the event of a spill, the following actions should be taken:

- Take immediate action to stop and contain the spill.
- Notify the MACTEC–ERS site manager, who will notify the MACTEC–ERS project compliance officer. The project compliance officer will report petroleum spills that exceed 25 gallons to DOE and other regulatory authorities (e.g., State, EPA regional administrator) within 24 hours.
- Remove all potential fire hazards and ensure that the spill poses no immediate hazards.
- Avoid vapor inhalation and skin contact with the spilled material.

Spill cleanup of petroleum products will entail

- Removing all stained soil and overexcavating a few inches.
- Placing the excavated material on a plastic tarpaulin.
- Periodic mixing of the soil with a shovel or by lifting the corners of the tarp and alternating ends to roll the material.

When the soil no longer contains a flammable concentration of organic material, the material can be disposed of at a municipal landfill or at Cheney Repository if it qualifies as RRM.

Management of other spilled material will be conducted in accordance with applicable regulations. For all spills, field personnel must contact the project compliance officer for the regulatory requirements pertinent to specific types of spill cleanup and notifications.

9.8.5 Waste Transportation and Disposal

Regulated wastes will be transported in accordance with DOT regulations and disposed of in compliance with Federal and State regulations and the permit or licensing requirements of the receiving facility. See Section 7 of the IDW Plan for more detailed information. Any questions regarding the off-site shipment of regulated wastes should be directed to the project compliance officer.

10.0 Health and Safety

The site-specific health and safety plan (DOE 1997c) has been prepared for the Rifle UMTRA Project site in accordance with applicable parts of 29 CFR 1910 (General Industry Standards), 29 CFR 1926 (Construction Safety Standards), the contractor's health and safety policies, the UMTRA Project Environmental Health and Safety Plan, UMTRA–DOE/AL–150224.006, and the DOE Headquarters Environmental Safety and Health/Office of Environmental Management interim document *Handbook for Occupational Health and Safety During Hazardous Waste Activities*, DOE/EH–0478. The health and safety policies, procedures, and hazard analysis referenced in this plan incorporate and take precedence over previous health and safety documentation.

All fieldwork will be performed according to the site-specific health and safety requirements developed for each task.

11.0 Logistics and Schedule

11.1 Work Readiness Review

A work readiness review (WRR) will be conducted by MACTEC–ERS at the GJO before the field team mobilizes for drilling. The purpose of the readiness review is to ensure that all personnel, facilities, systems, and processes are ready before the start of the fieldwork and to minimize the possibility of delays and problems due to incomplete planning and preparations.

Examples of specific topics that will be addressed include health and safety monitoring and training, logistics, schedule, DQOs, personnel, waste management issues, training requirements and certification, and site access and security.

The scope of the WRR will be defined by the following checklist, which will be more fully developed before the WRR. The checklist will include at least the following major categories:

- Site Access Requirements
- Review and Approval of Project Documents
- Project Team Members and Responsibilities
- Schedule and Vehicle Requirements
- Communication Requirements
- Training
- Site Health and Safety
- Field Activities
- Field Base Maps
- Field Notebooks
- Attendees
- Approval Authority
- Compliance Issues
- IDW Disposal

11.2 Schedule

Table 11S1. Schedule of Fieldwork at the New and Old Rifle Sites

Activity	Start	Finish
Preparation for Fieldwork	02/19/98	03/18/98
Readiness Review Meeting	03/19/98	03/19/98
Mobilize to Old Rifle Site for Drilling/Field work	03/27/98	03/27/98
Unload/Set up/Inspection/Pre-Entry Briefing	03/30/98	03/30/98
Install Standpipes; Install Alluvial, Wasatch, and Stilling Wells at Old Rifle site	03/31/98	04/28/98
Collect Ecological Field Samples	03/31/98	04/02/98
Laboratory Analysis of Ecological Samples	04/03/98	06/05/98
Develop Permanent Wells at Old Rifle site	04/29/98	05/04/98
Collect Subpile Soil Samples at Old Rifle site	04/29/98	04/29/98
Conduct Single-Well Slug Tests and Well-Pair Aquifer Tests at Old Rifle site	05/05/98	05/14/98
Mobilize to New Rifle for Drilling/Field Work	05/15/98	05/15/98
Collect Hydropunch Samples	05/18/98	05/28/98
Install Monitor, Observation, Pumping, and Stilling Wells at New Rifle site	05/29/98	07/16/98
Develop Permanent Wells at New Rifle site	07/17/98	07/30/98
Collect Subpile Soil Samples at New Rifle site	07/17/98	07/17/98
Prepare Soil Samples for Laboratory Analysis	07/20/98	07/24/98
Laboratory Analysis of Leachate	07/27/98	09/28/98
Conduct Land Surveys at both sites	07/31/98	08/13/98
Conduct Aquifer Tests at New Rifle site	07/31/98	08/07/98
Install Data Loggers in New Wells	08/10/98	08/11/98
Remove Temporary Field Stand Pipes at Old Rifle site	08/10/98	08/10/98
Restore Site	08/11/98	08/12/98
Recover Data Loggers	08/12/98	08/12/99
Demobilize Drill Rig/Crew from Rifle	08/13/98	08/13/98
Collect Ground-Water Samples	08/24/98	08/28/98
Laboratory Analysis of Ground-Water Samples	08/31/98	11/02/98

12.0 Deliverables

The major deliverables for this project are (1) data reports and (2) revision 1 of the SOWP.

Data reports will be provided for several aspects of the fieldwork. Each data report will present the data collected during the fieldwork, data reduction methods, and interpretation of results. Separate data reports will be provided for aquifer test analyses and hydrologic interpretation.

The Draft SOWP will be revised to include results of the field investigation and an evaluation of alternative remedial technologies. The data reports will provide the basis for the revision of the SOWP and the recommended approach to remediation.

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